

GPM for Tropical Meteorology

MJO Family

Typhoon/Hurricane

Precipitation Systems

Tetsuo Nakazawa

Meteorological Research Institute/JMA

MJO Family

- The past decade has witnessed an expeditious progress in the study of the MJO: Its **large-scale and multiscale structures** are better described, its **scale interaction** is recognized, its **broad influences on tropical and extratropical weather and climate** are increasingly appreciated, and its **mechanisms for disturbing the ocean** are further comprehended.
- Yet we are facing great difficulties in accurately simulating and predicting the MJO using sophisticated global weather forecast and climate models, and we are **unable to explain such difficulties based on existing theories of the MJO**. It is fair to say that the MJO **remains an unmet challenge to our understanding of the tropical atmosphere** and to our ability to simulate and predict its variability.

1-layer shallow water eq. in equatorial beta plane

$n=-1$: Eastward Kelvin wave ($v=0$)

$n=0$: Eastward inertia-gravity wave

Westward mixed Rossby gravity wave

$n=1,2,\dots$:

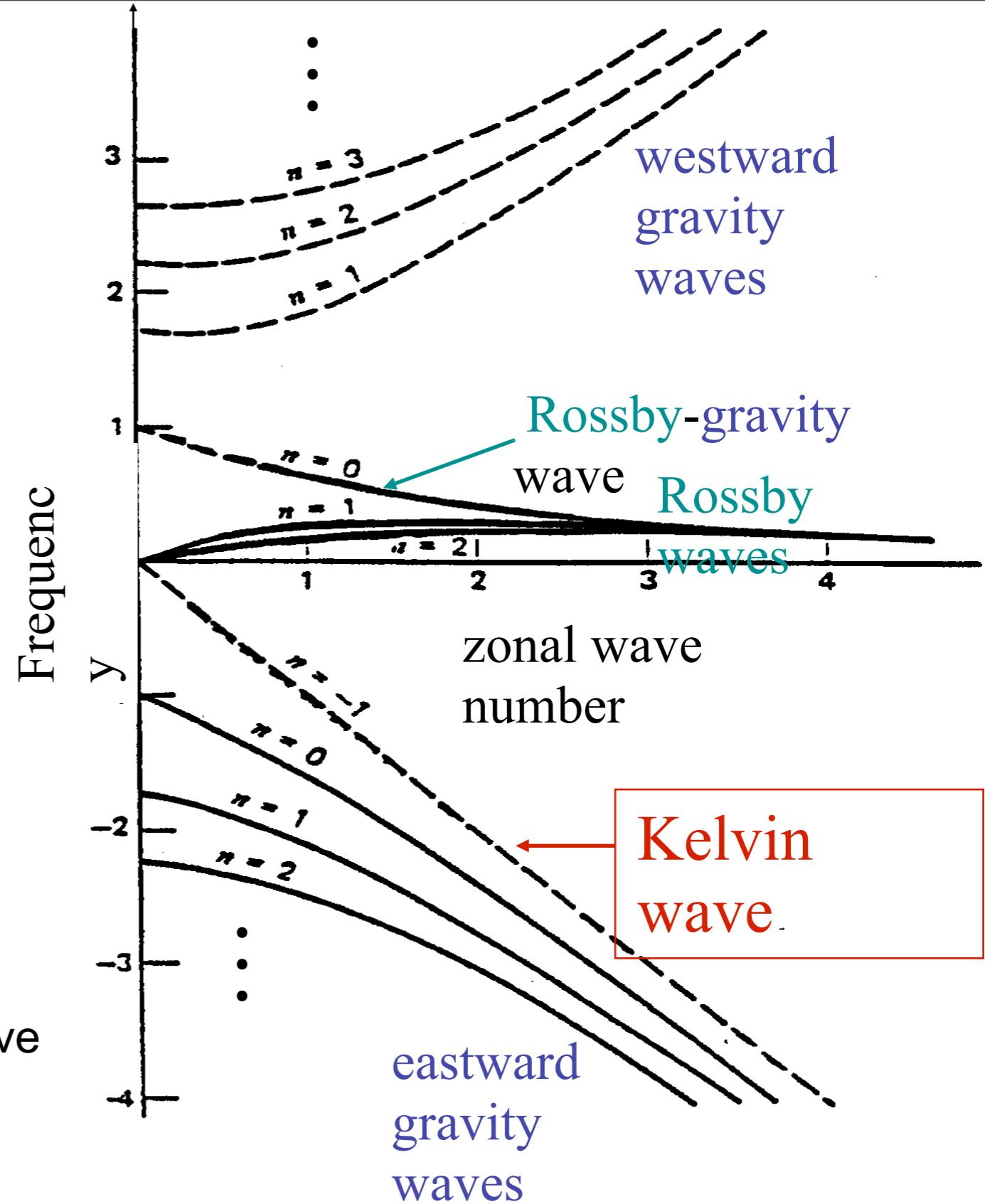
Eastward inertia-gravity wave

Westward Rossby & inertia-gravity wave

$$\frac{d^2 \hat{v}}{d\lambda^2} + \left(\omega^2 - \mu^2 + \frac{\mu}{\omega} - \lambda^2 \right) \hat{v}(\lambda) = 0$$



$$\omega^2 - \mu^2 + \frac{\mu}{\omega} = 2n + 1$$



18-year OLR Wavenumber-Frequency Analysis Separate Symmetric/Asymmetric Components

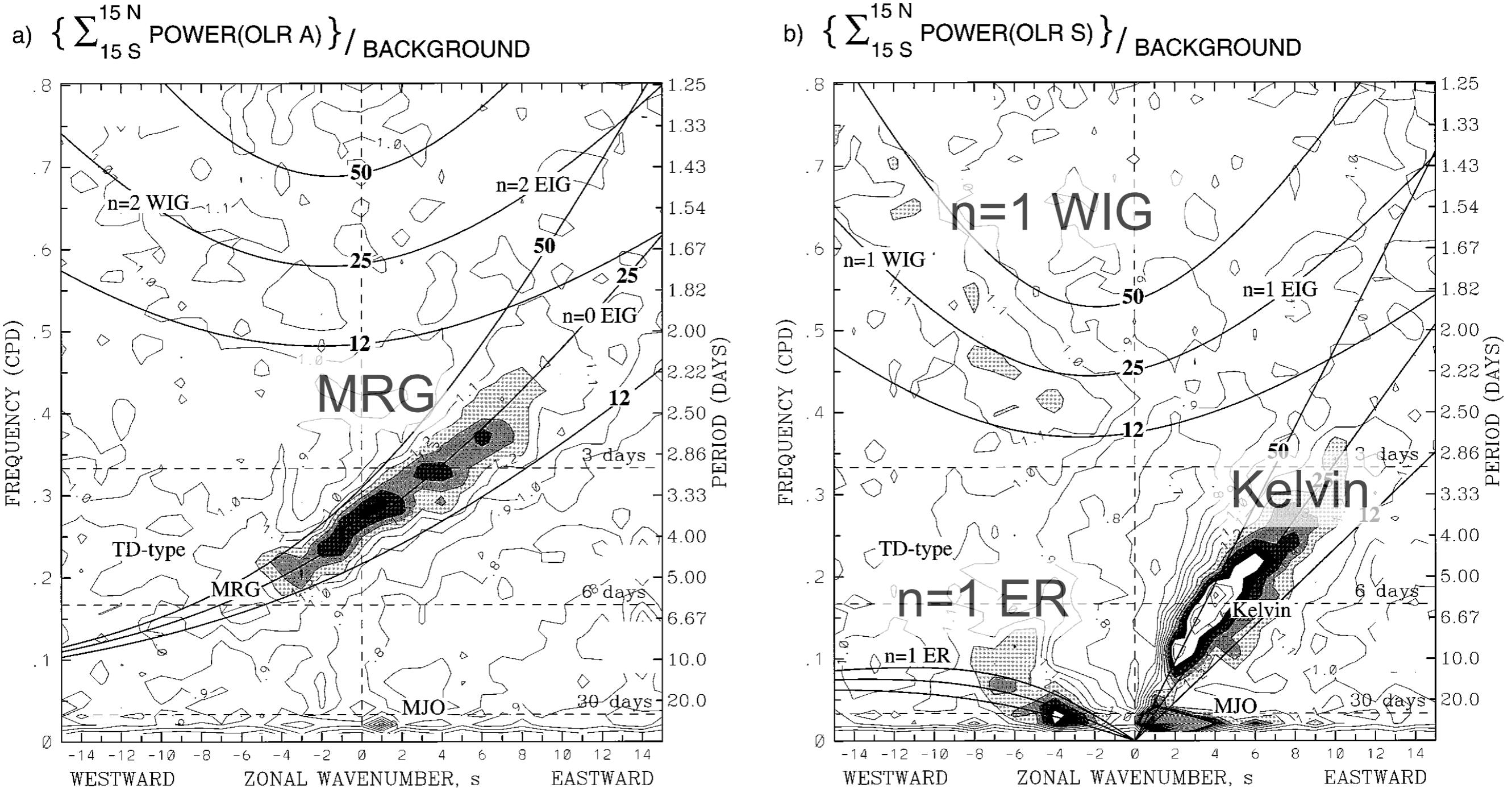
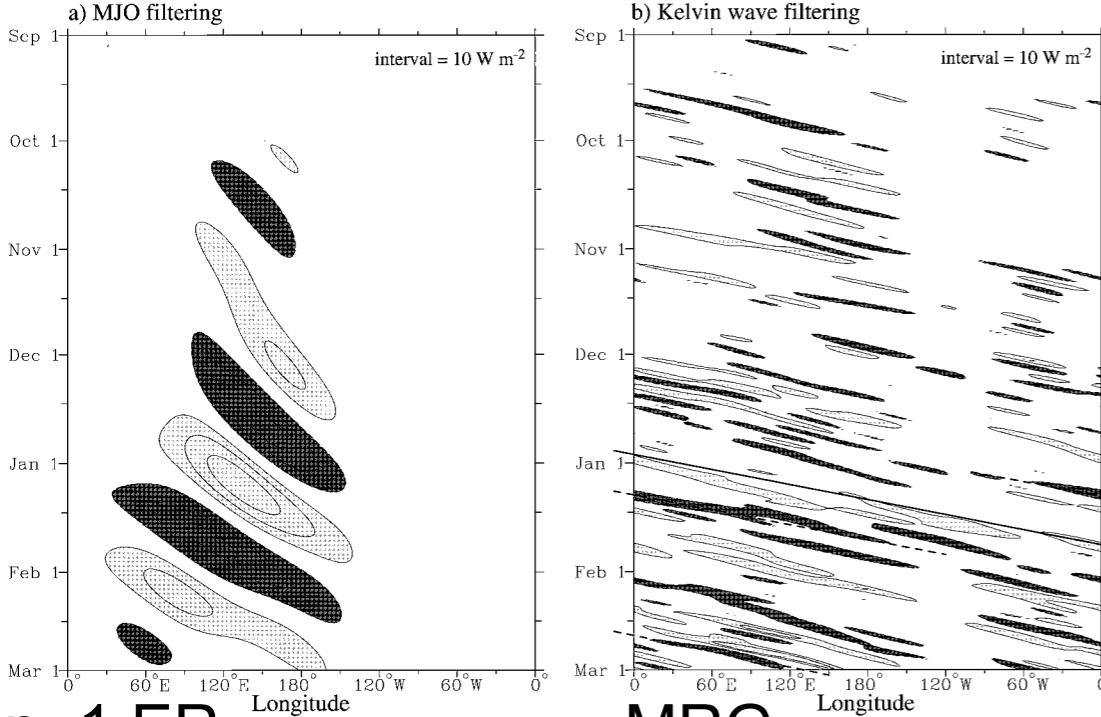


FIG. 3. (a) The antisymmetric OLR power of Fig. 1a divided by the background power of Fig. 2. Contour interval is 0.1, and shading begins at a value of 1.1 for which the spectral signatures are statistically significantly above the background at the 95% level (based on 500 dof). Superimposed are the dispersion curves of the even meridional mode-numbered equatorial waves for the three equivalent depths of $h = 12, 25$, and 50 m. (b) Same as in panel a except for the symmetric component of OLR of Fig. 1b and the corresponding odd meridional mode-numbered equatorial waves. Frequency spectral bandwidth is 1/96 cpd.

Individual Wave Separation

MJO

Kelvin



$n=1$ ER

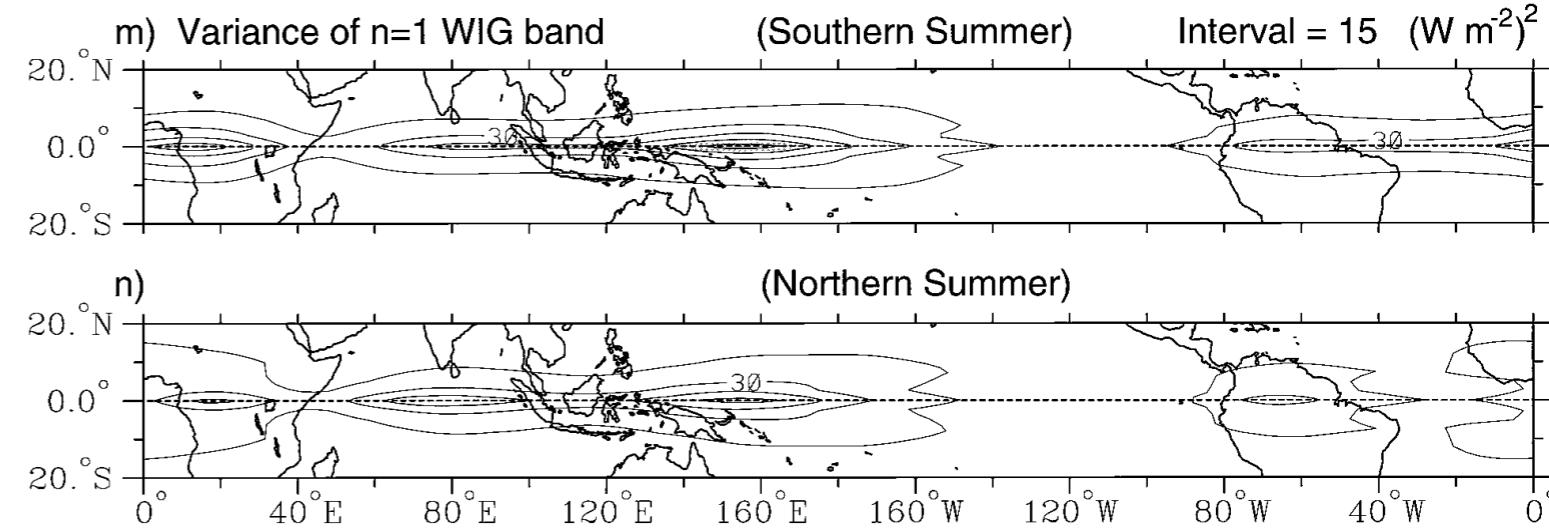
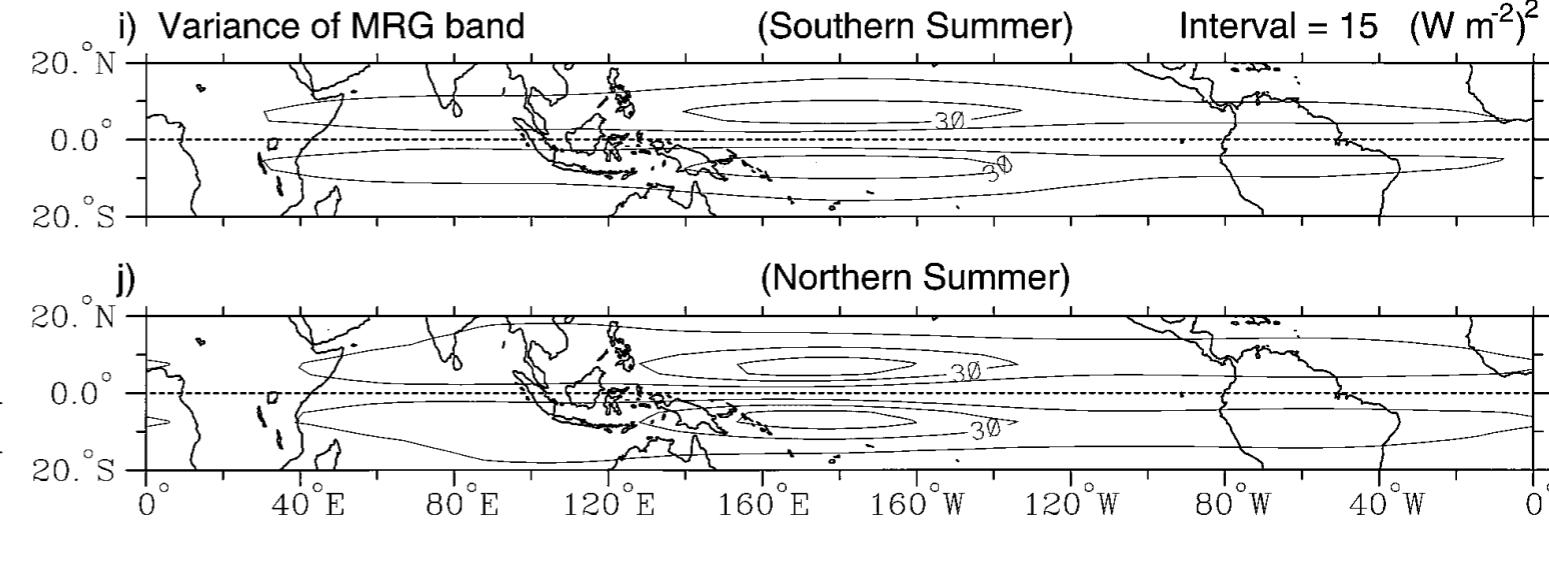
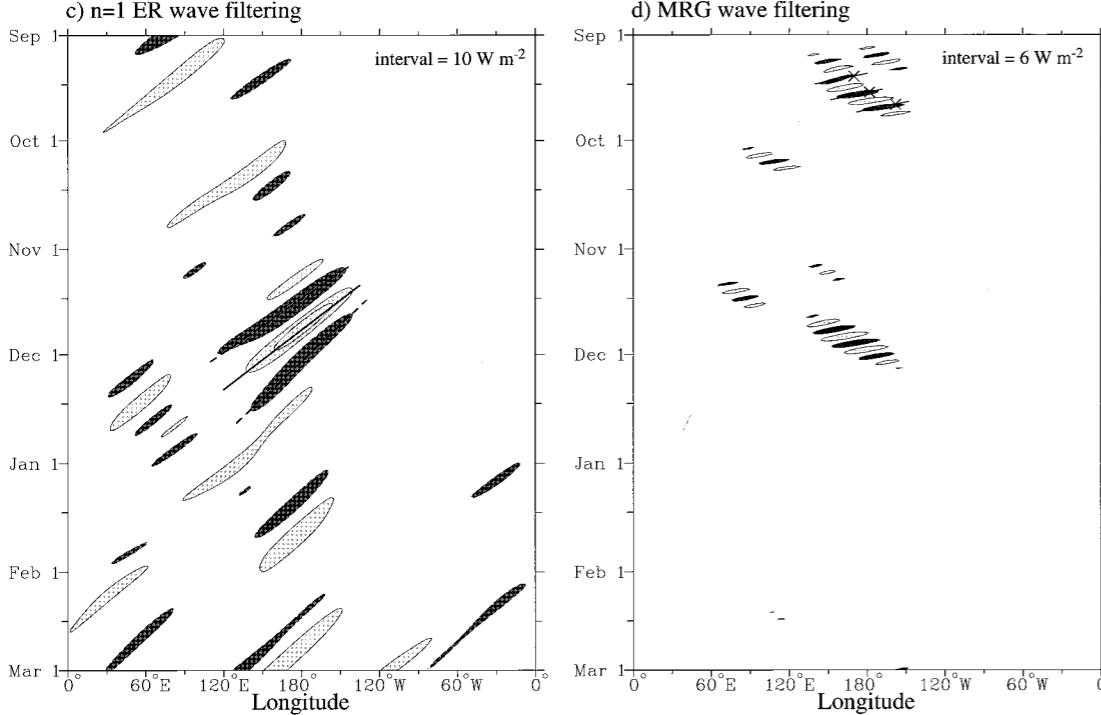
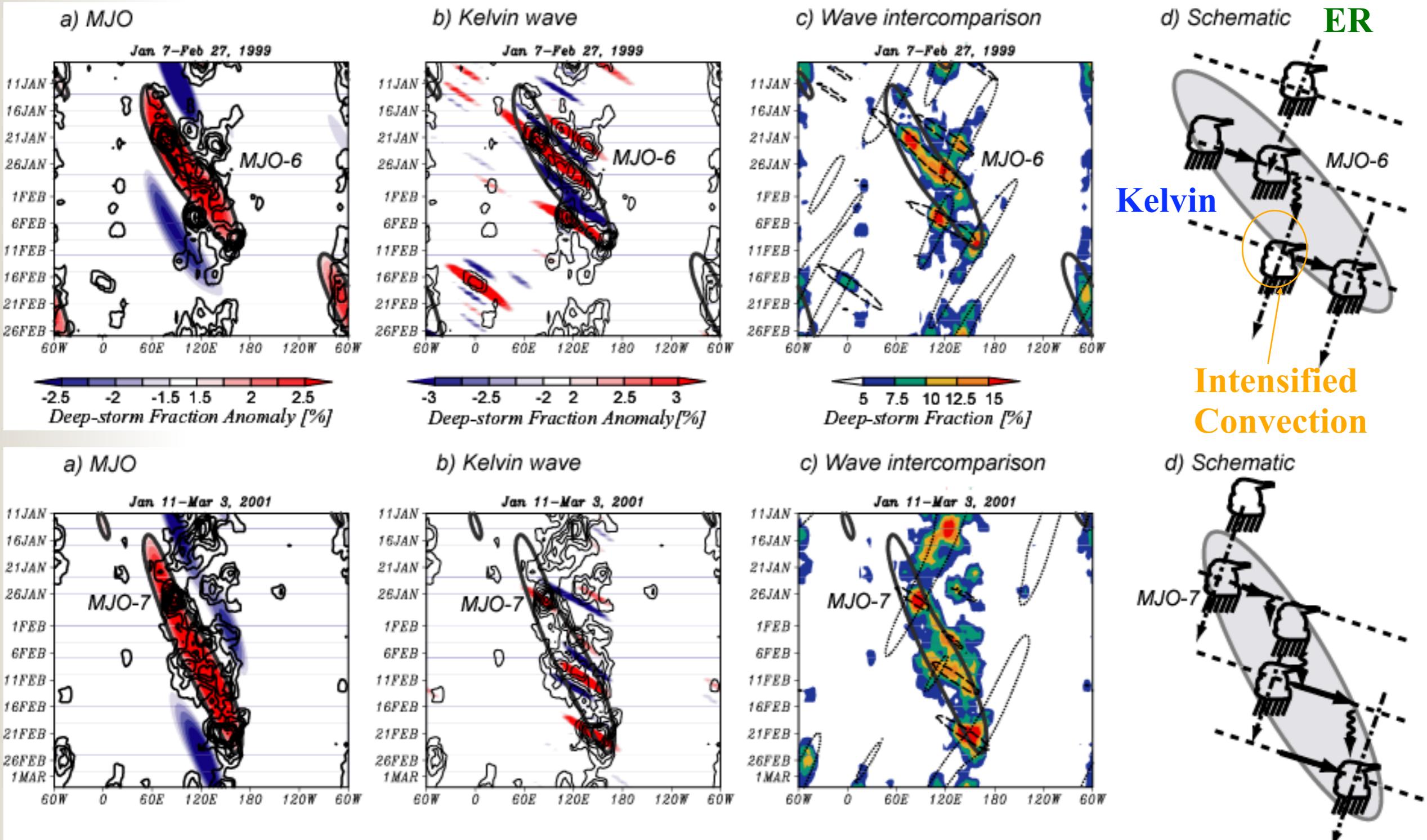


FIG. 9. (a) Time-longitude section of the OLR anomalies for the MJO-filtered band for the same 6-month sample period as Fig. 8, averaged for the latitudes from 10°S to 2.5°N. The zero contour has been omitted. Light shading for positive anomalies and dark shading and dashed contours for negative anomalies. (b) Same as in panel a except for the Kelvin wave-filtered band. (c) The $n = 1$ ER wave-filtered band. (d) The MRG wave-filtered band.

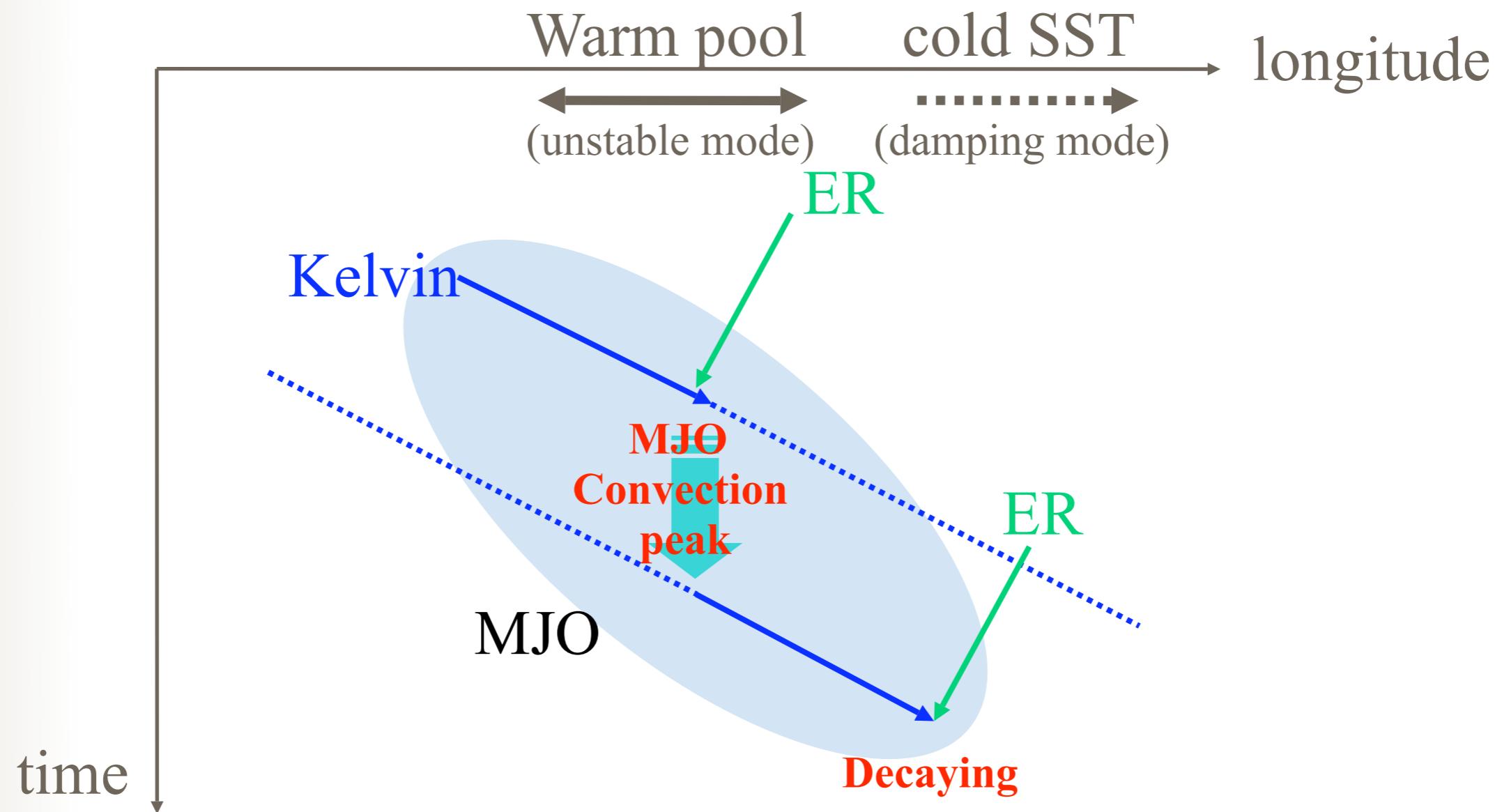
- Bandpass filtered TRMM precipitation data



Convection tends to intensify (decay) over the WP warm pool (in the east of the dateline) when a Kelvin wave meets an intruding ER wave.

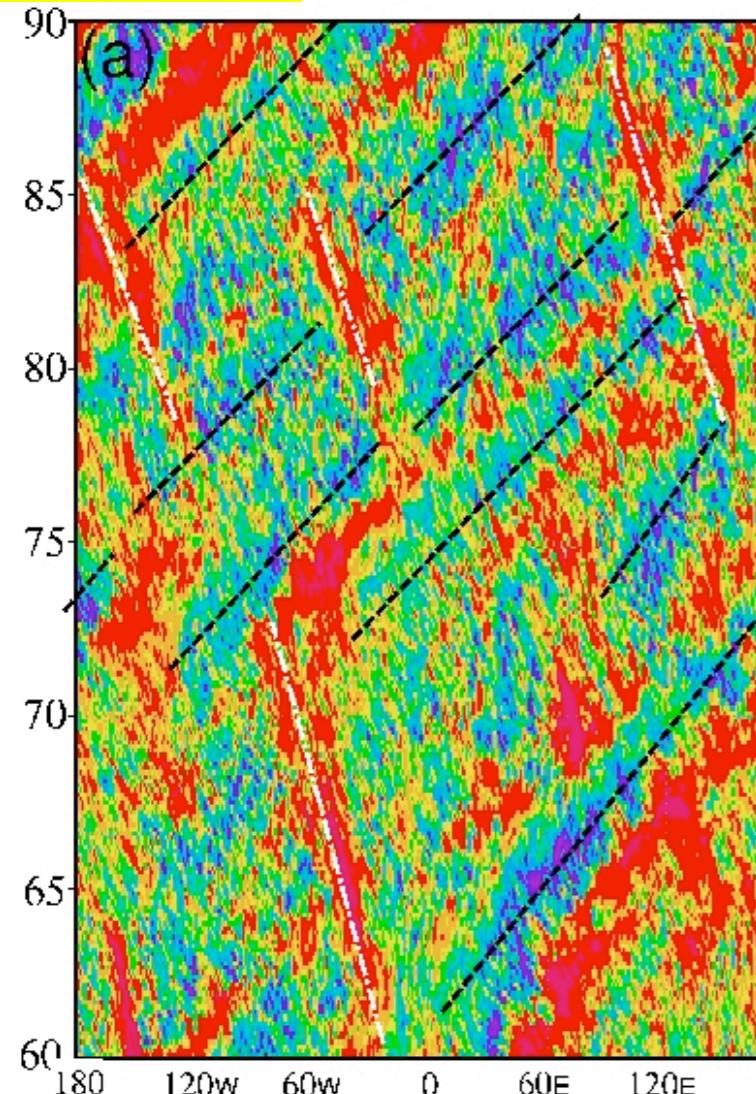
Masunaga and Kummerow(2006)

MJO schematic (austral summer)

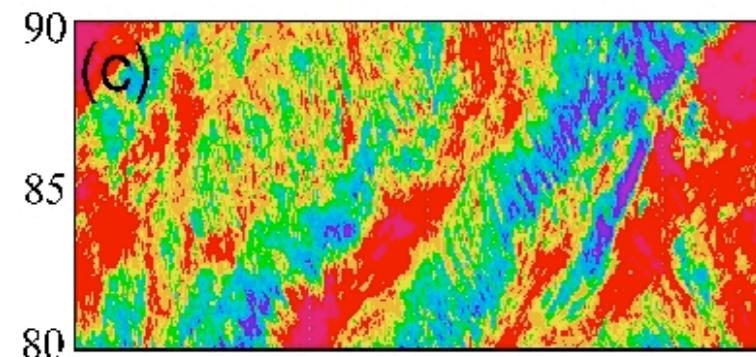
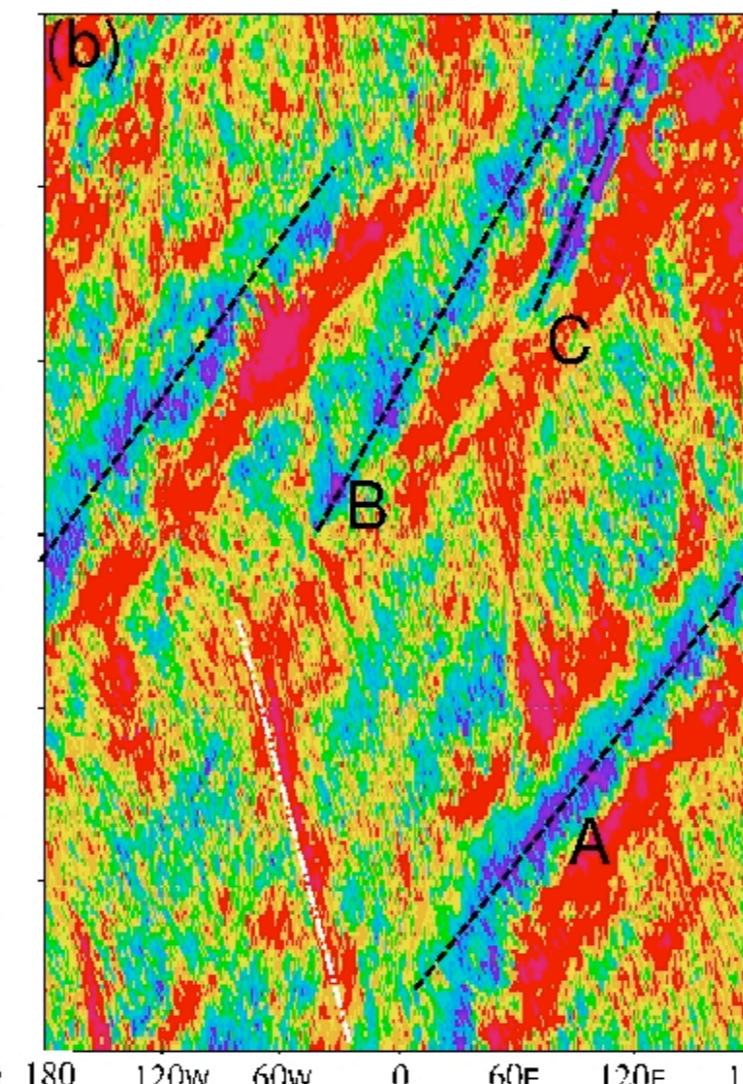


Hovmoller diagrams of OLR (2S-2N)

dx=14km

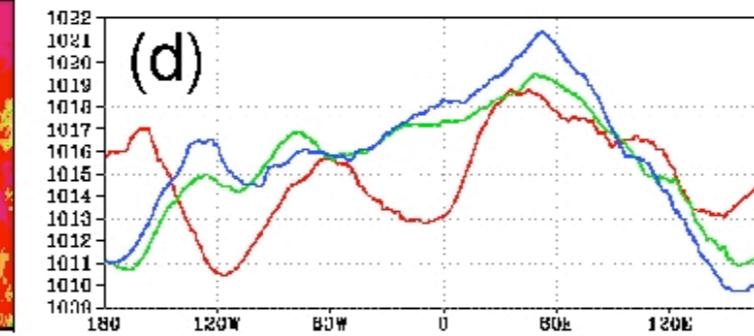


dx=7km



dx=3.5km

240 270 300



Eastward propagation of SCC

Westward motion of CC
 \rightarrow Lifetime about 2days

dx=14km:

20~25 days

\rightarrow fast propagation

dx=7km, dx=3.5km :

25-40 days

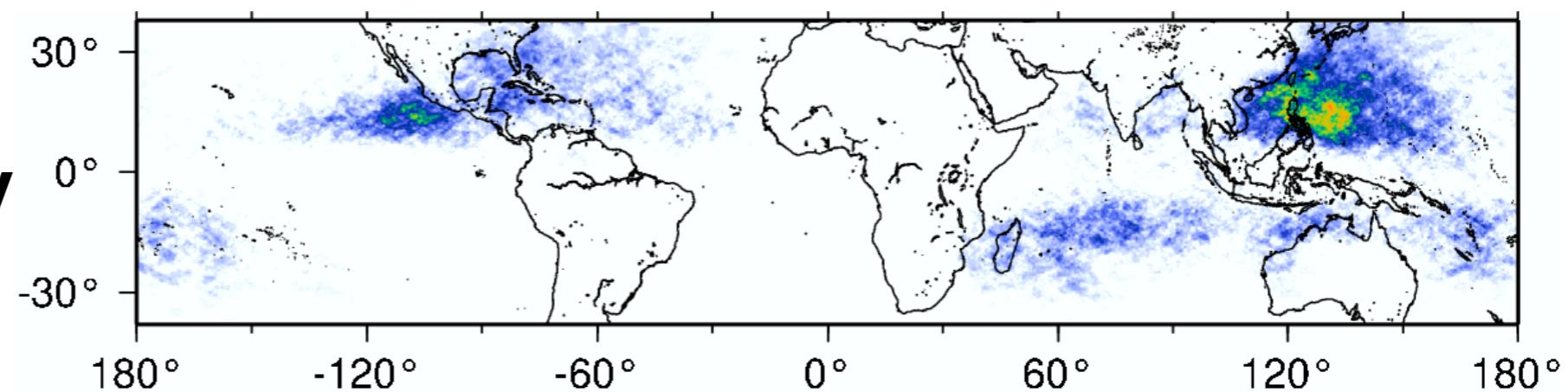
\rightarrow corresponding to MJO

\rightarrow also well organized
rather than $dx=14\text{km}$.

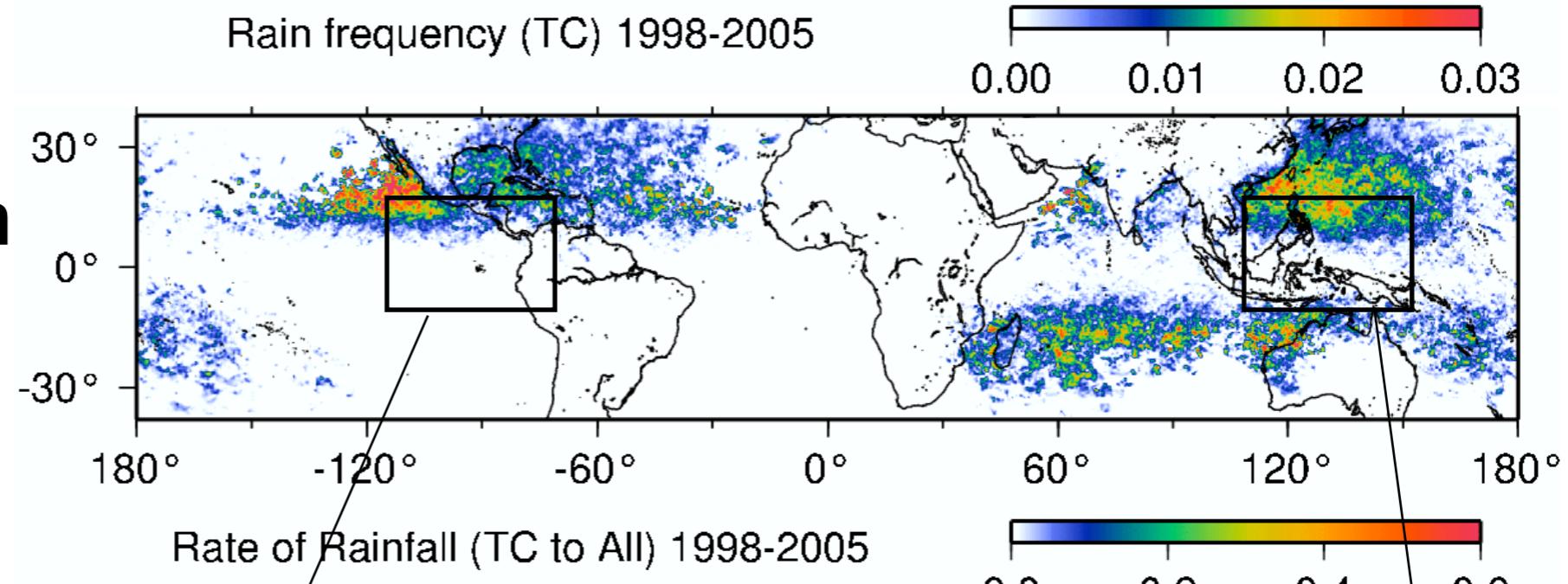


Typhoon/Hurricane

Rain Frequency due to TC

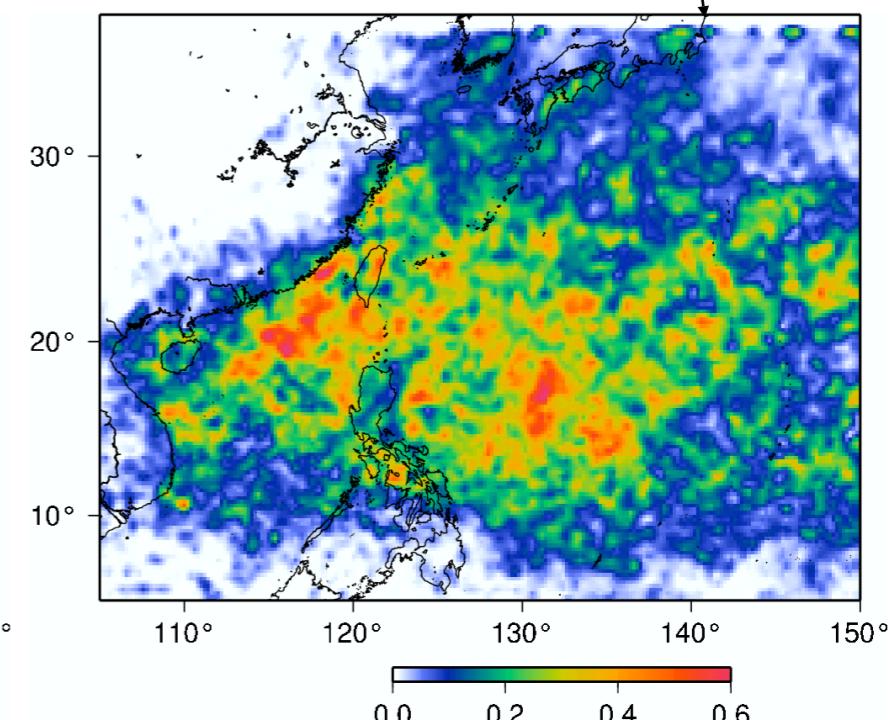
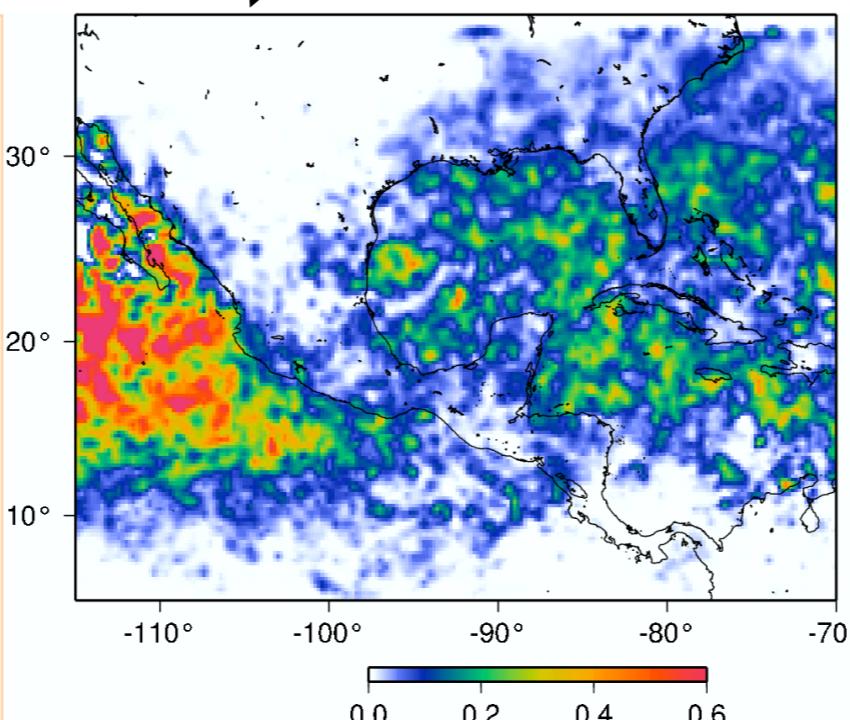


TC Contribution to Total Rainfall



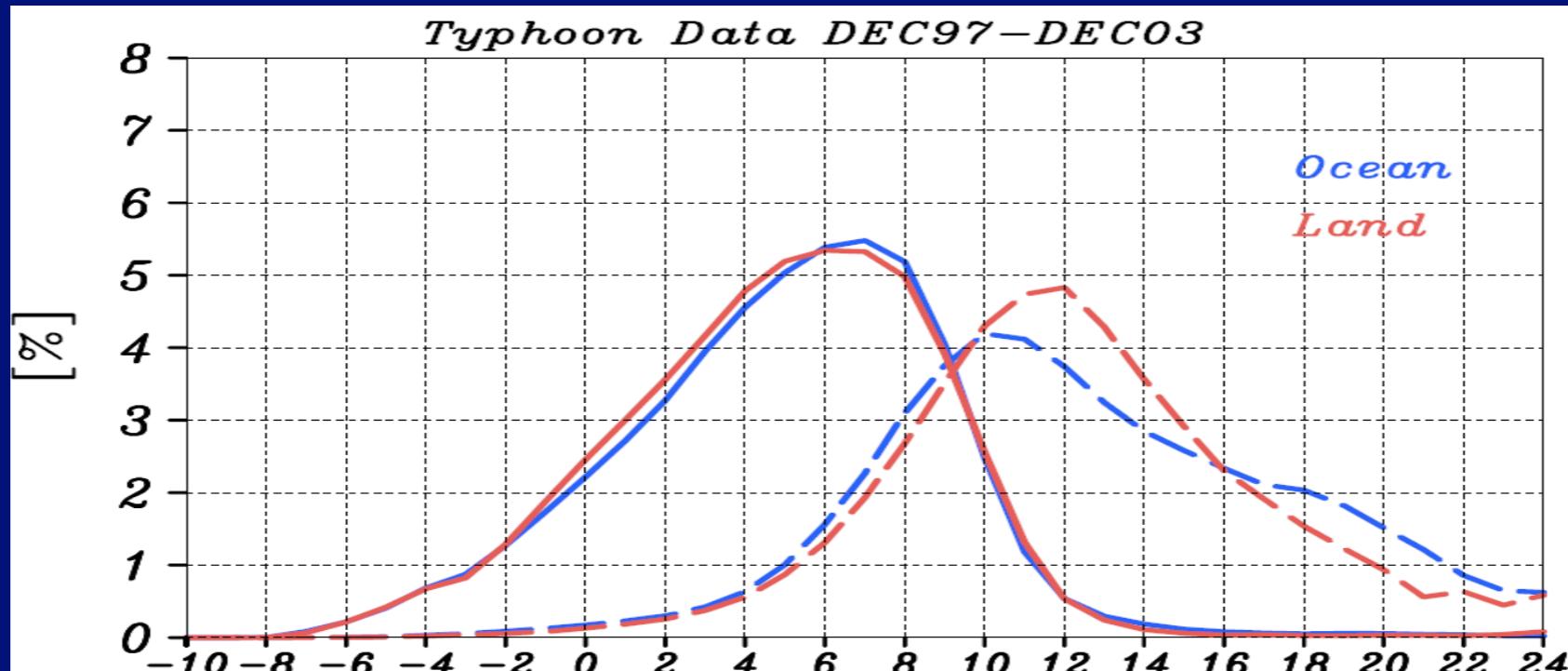
Off Mexico TC contribution is the highest, over 50 %, in some locations greater than 90%.

Seasonal Change or Local difference in TC structure would be examined when we have more samples.



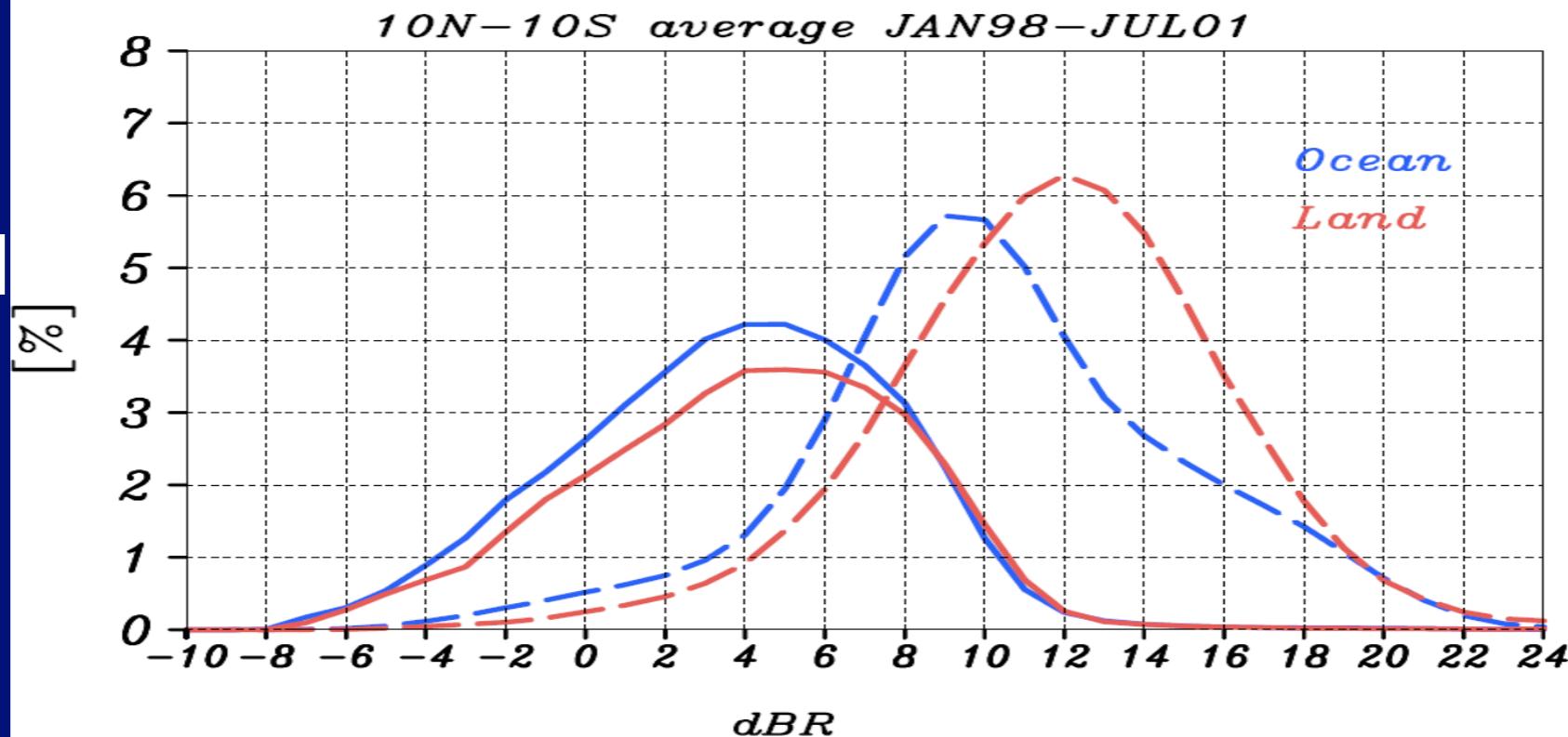
Contribution of each rain rate to total rain

TCs



mmhr⁻¹ 0.5 1 dB_R 5 10 50 100

Equatorial
-mean

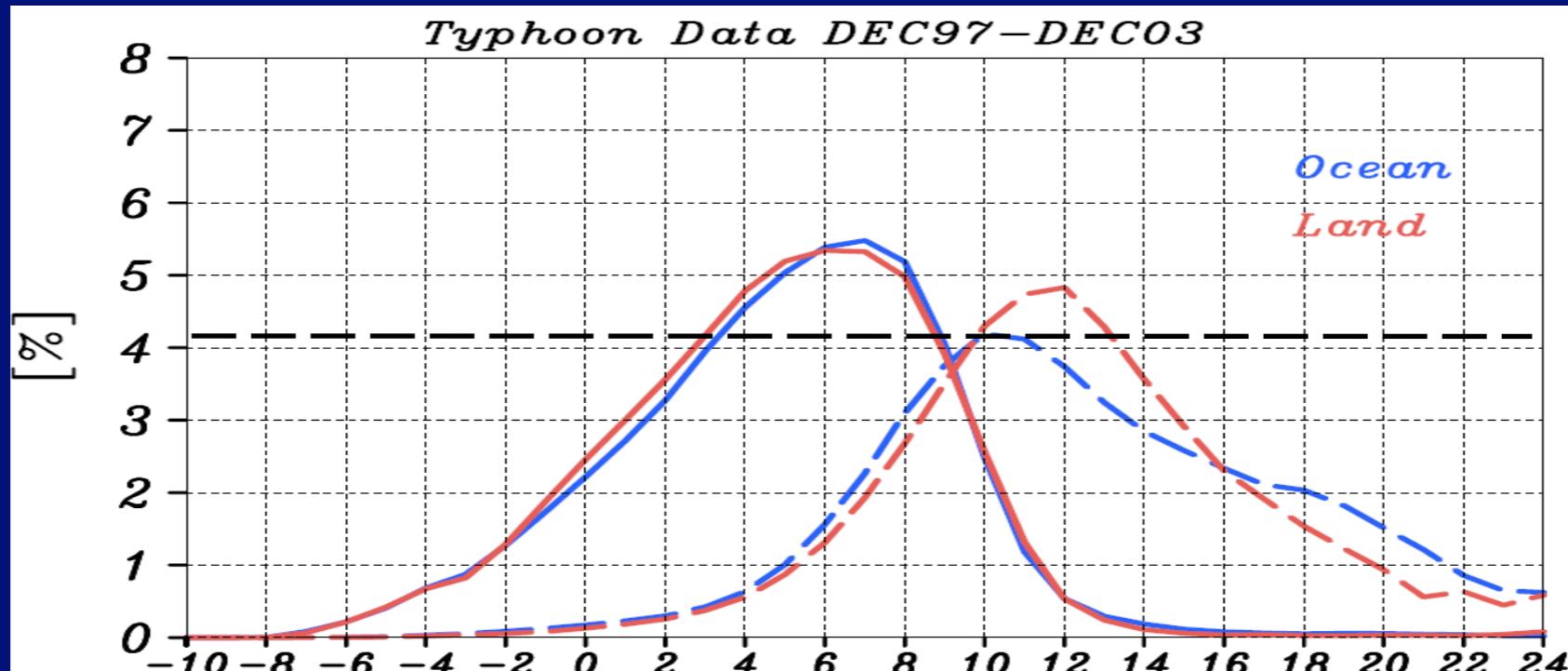


--Conv. —Strat. Ocean Land $dBR=10\log_{10}(\text{RainRate})$

Yokoyama and Takayabu(2006)

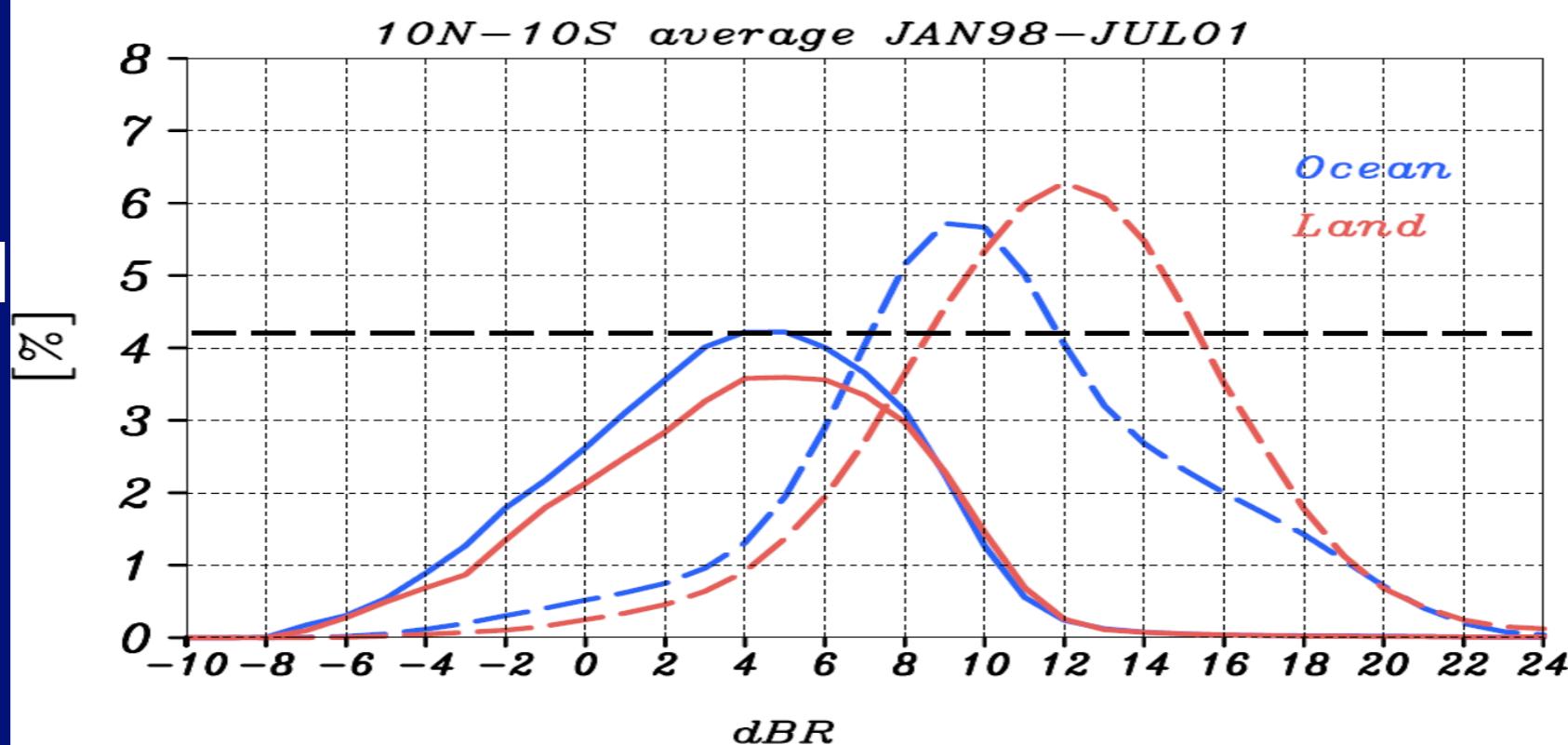
Contribution of each rain rate to total rain

TCs



Strt.>Cnv.

Equatorial
-mean

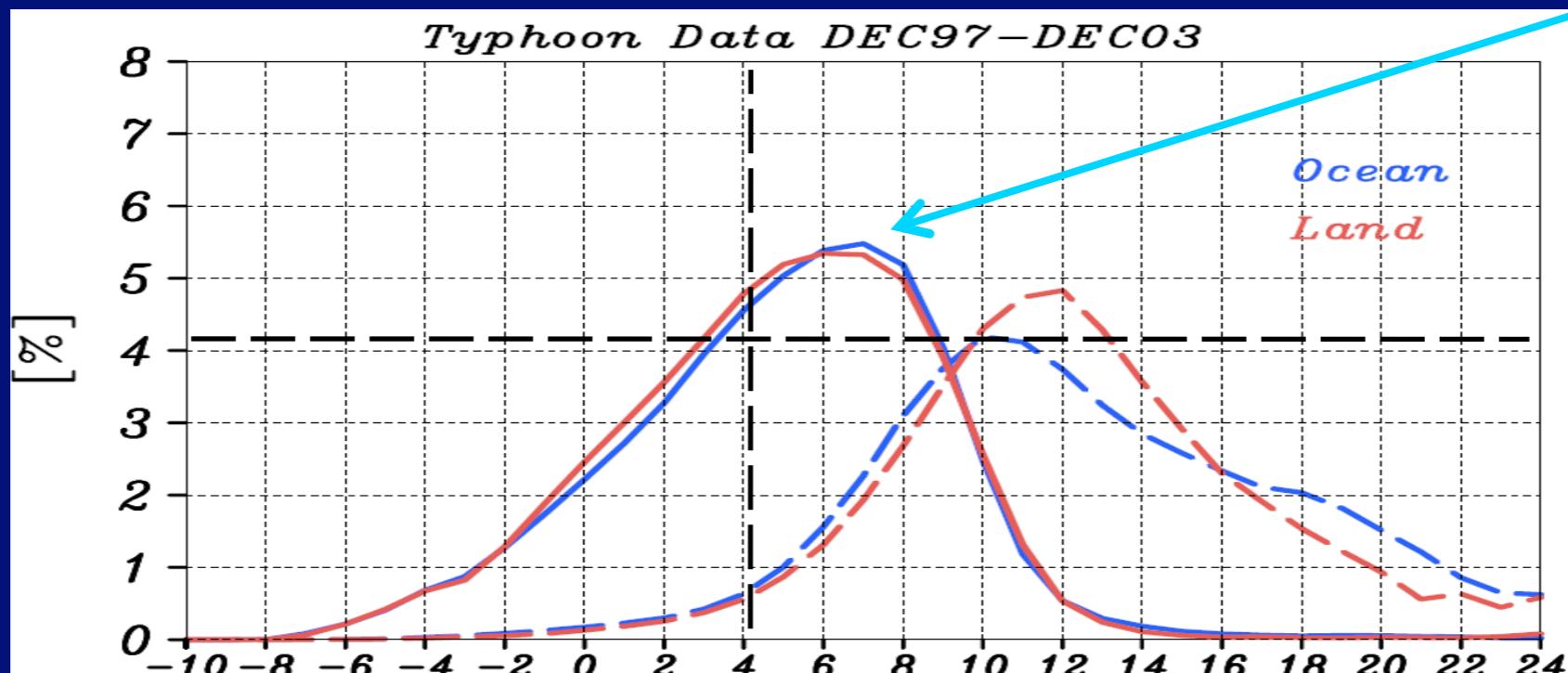


Strt.<Cnv.

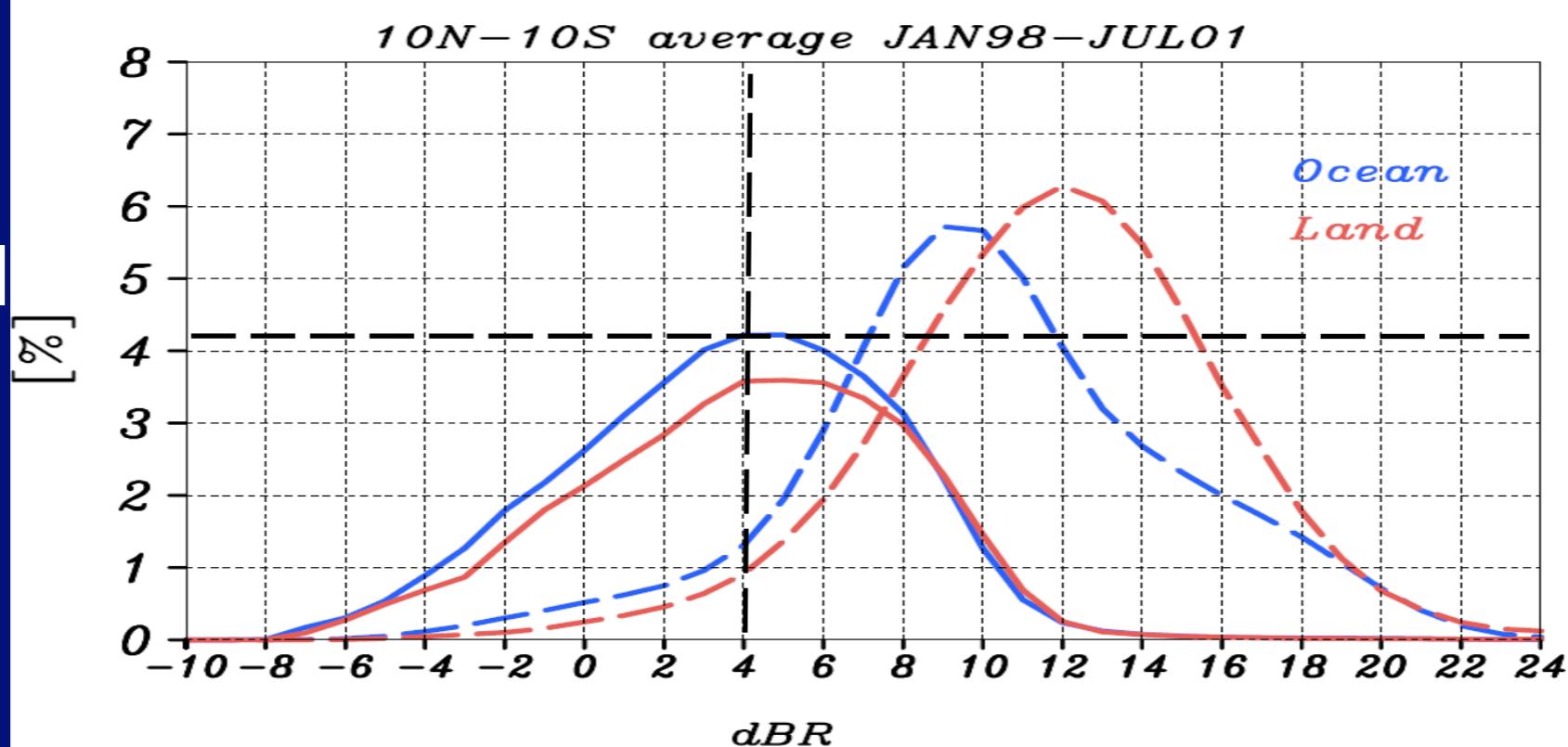
Contribution of each rain rate to total

**stronger
strat.**

TCs



Equatorial
-mean

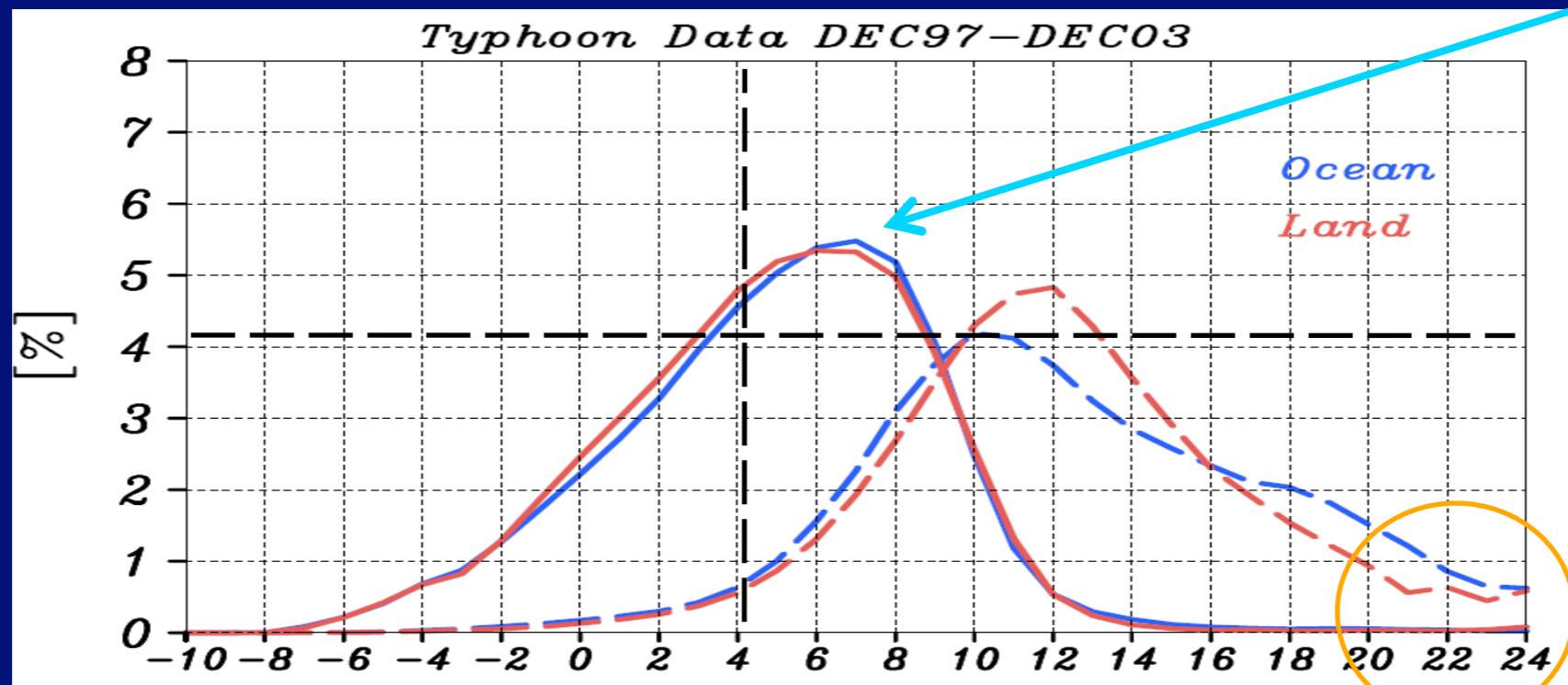


Strt.>Cnv.

Strt.<Cnv.

Contribution of each rain rate to total

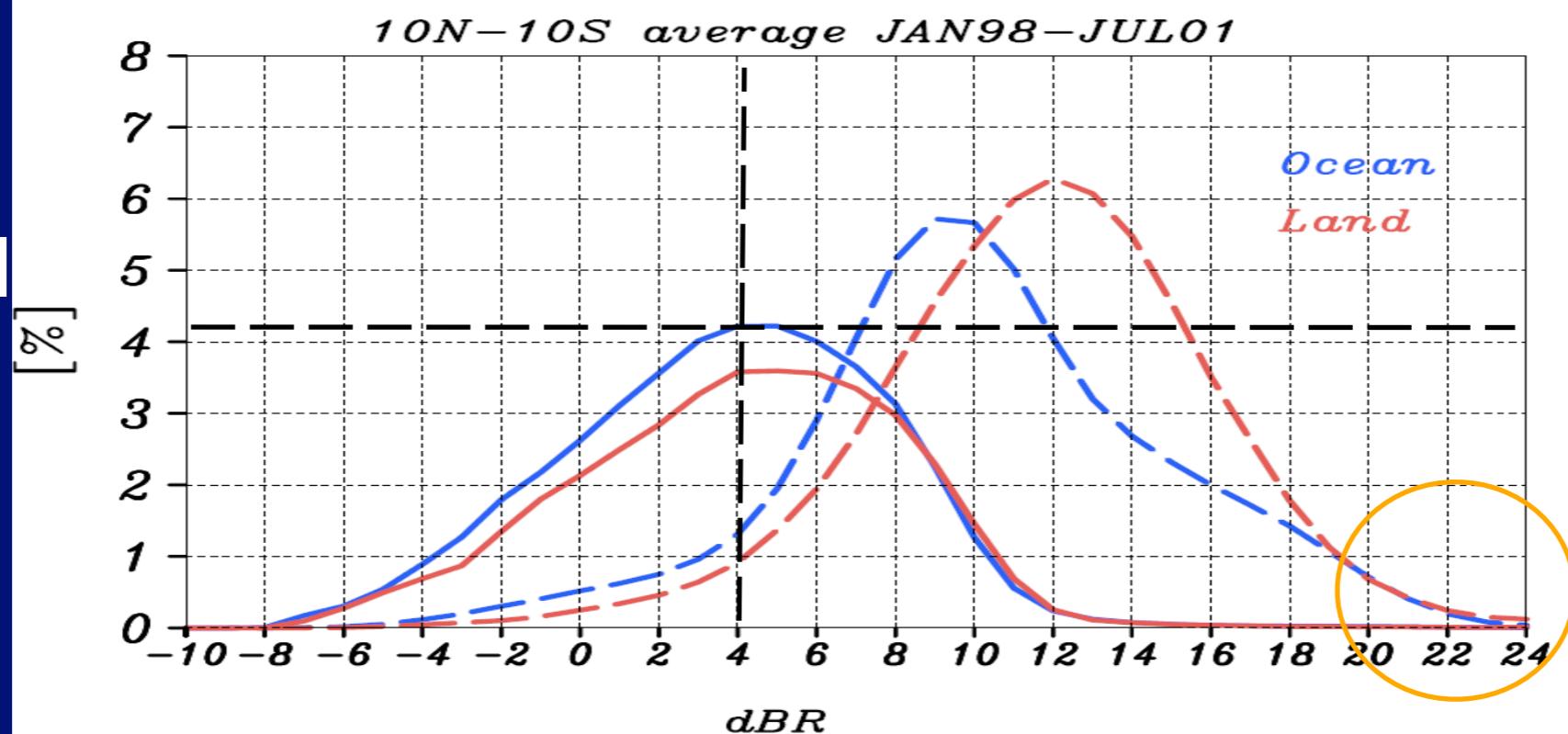
TCs



stronger
strat.

Strt.>Cnv.

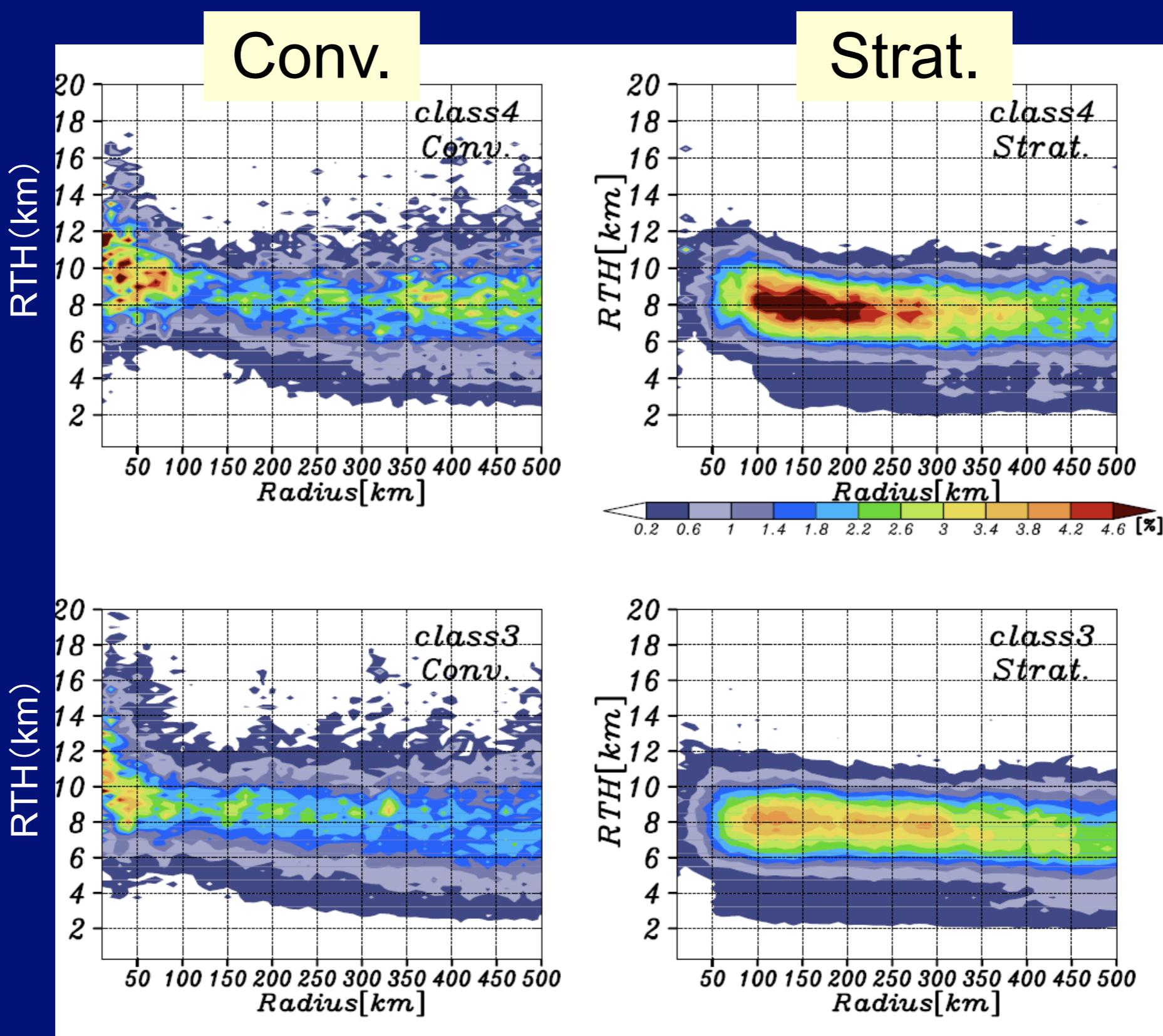
Equatorial
-mean



Strt.<Cnv.

Radial distribution of contribution of each RTH

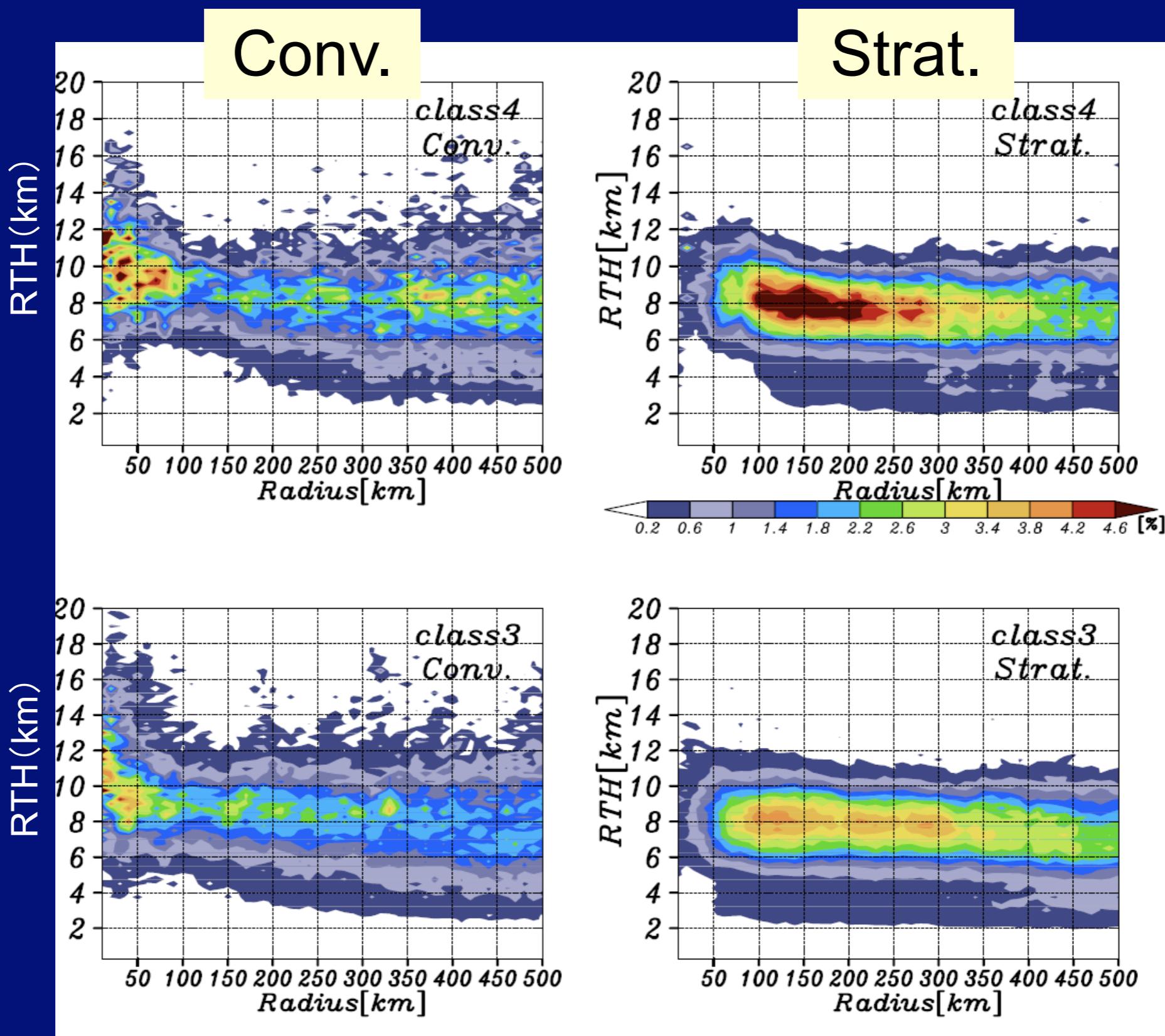
Class4



Class3

Radial distribution of contribution of each RTH

Class4



Class3

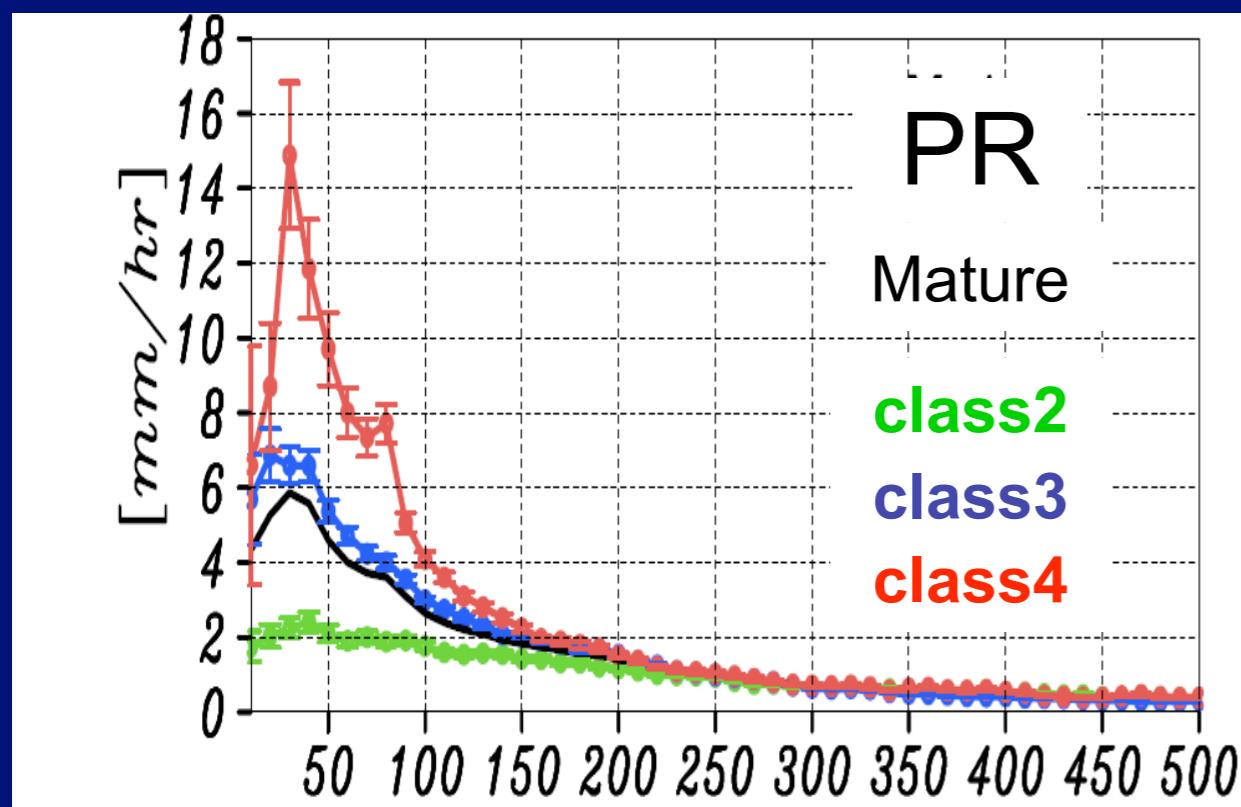
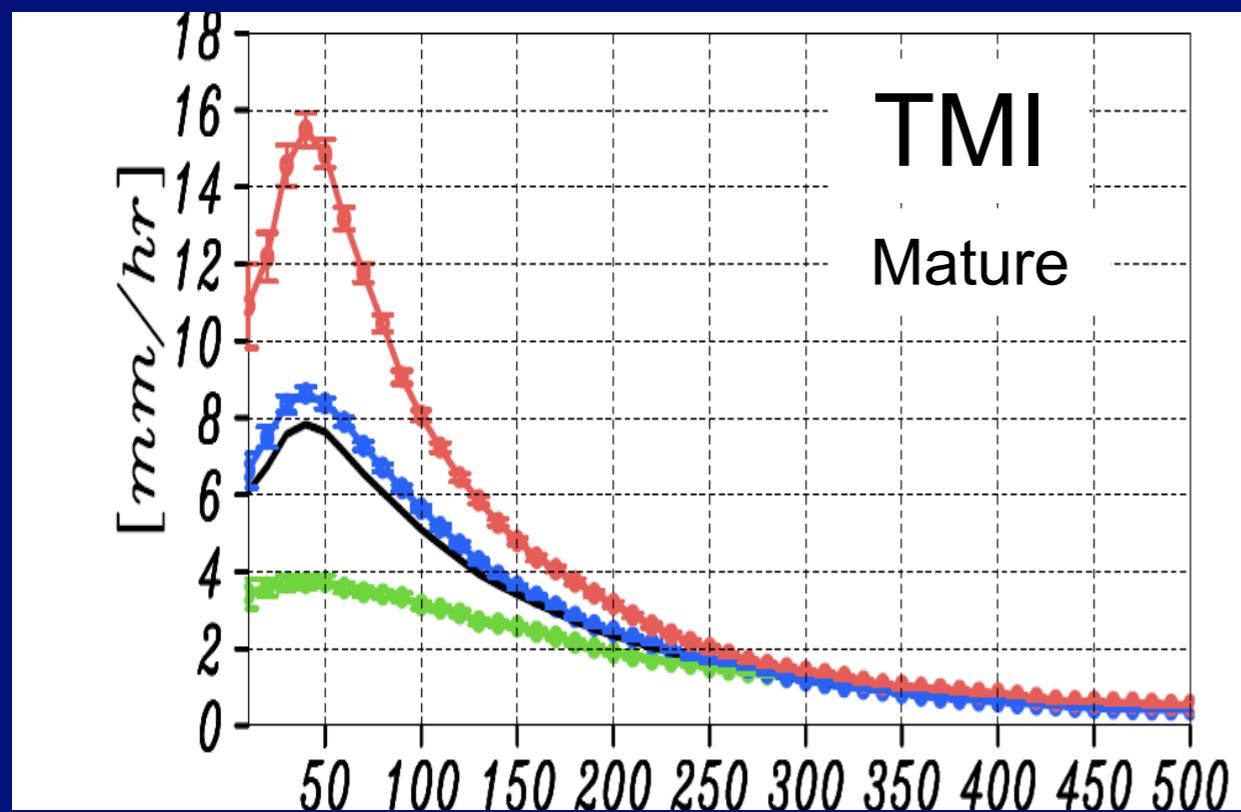
mature

Yokoyama and Takayabu(2006)

8km

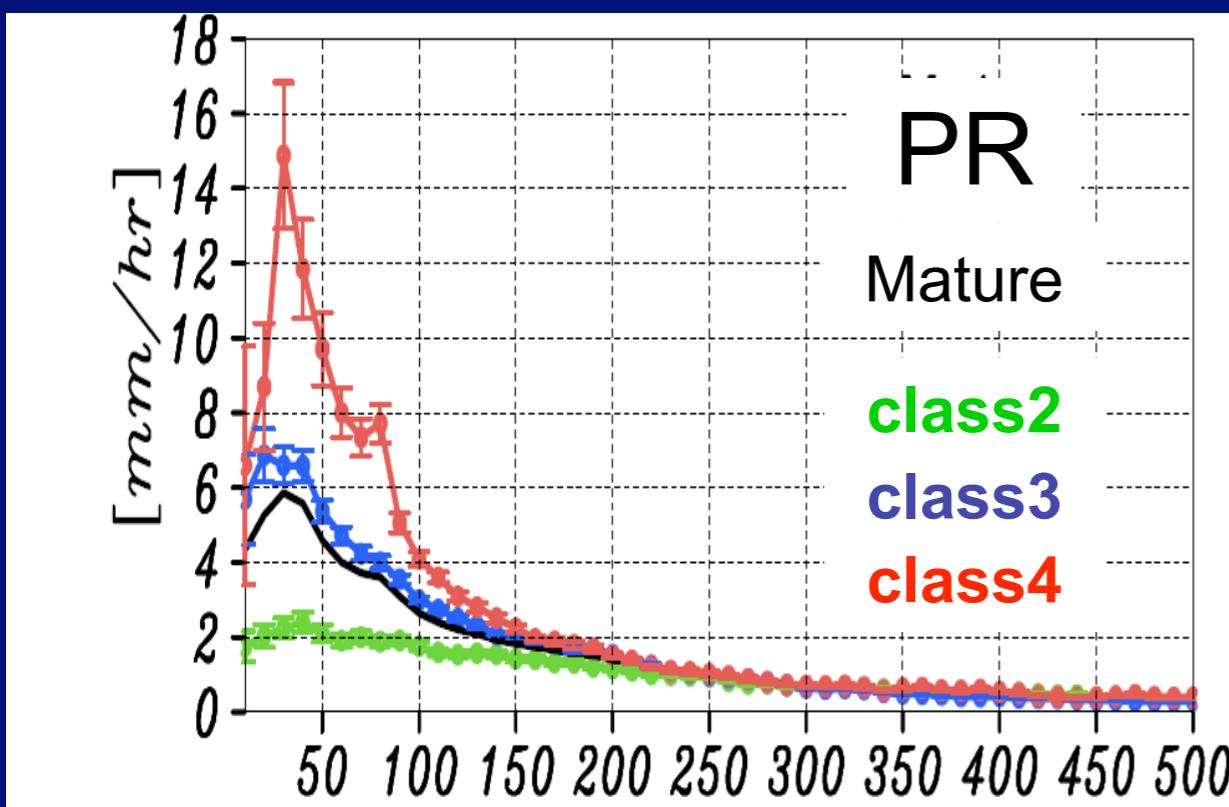
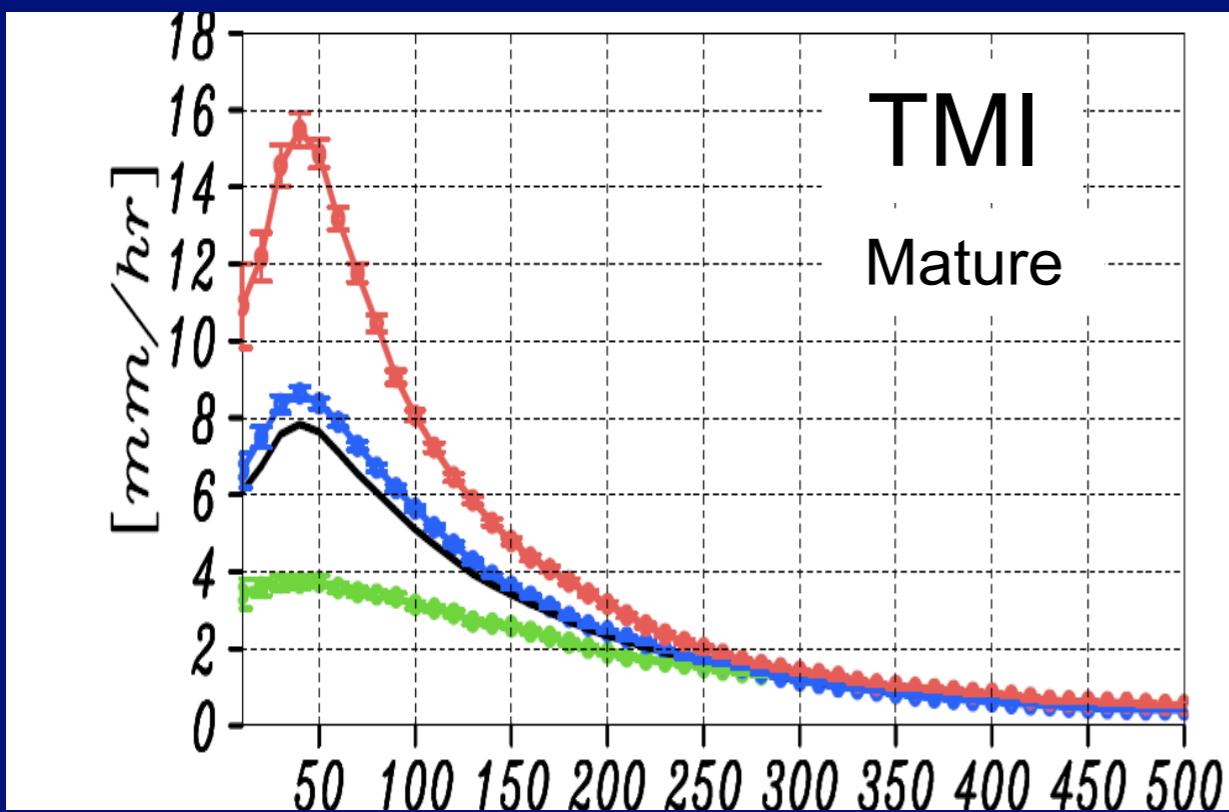
8km

Mean rain rate



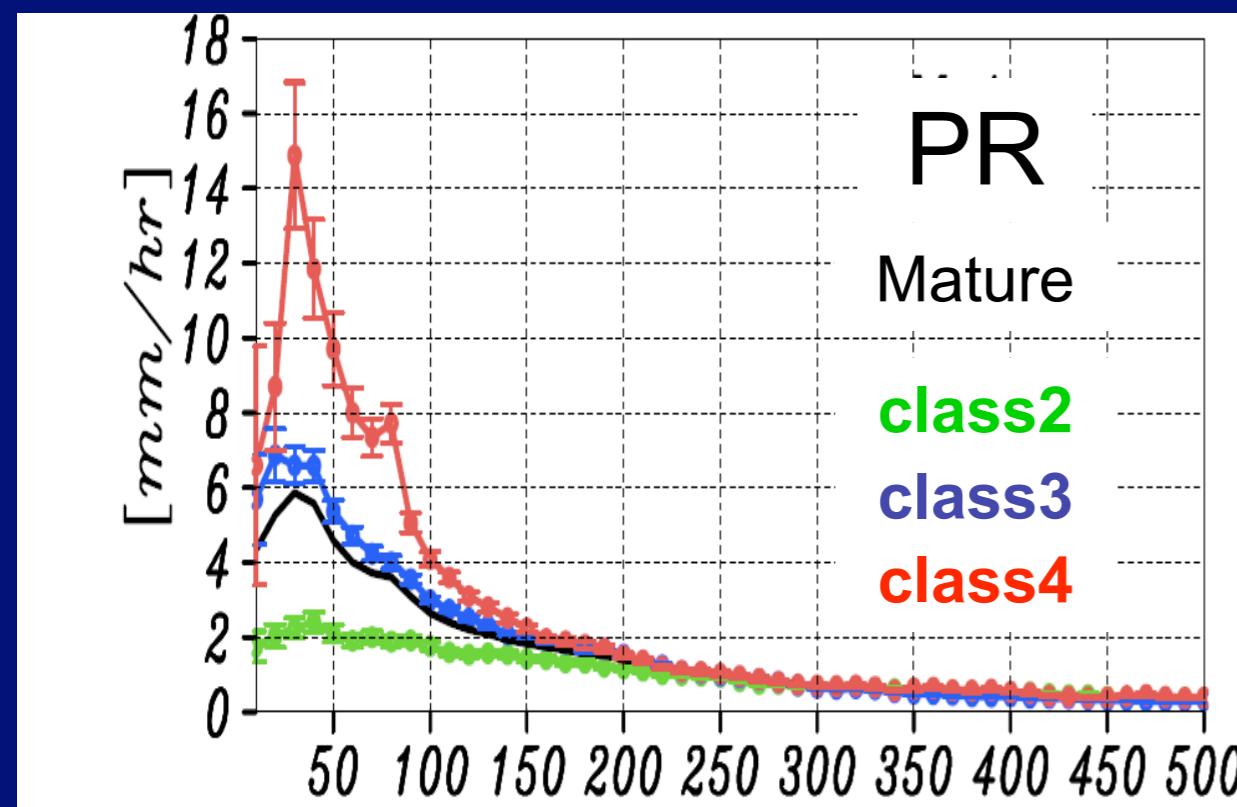
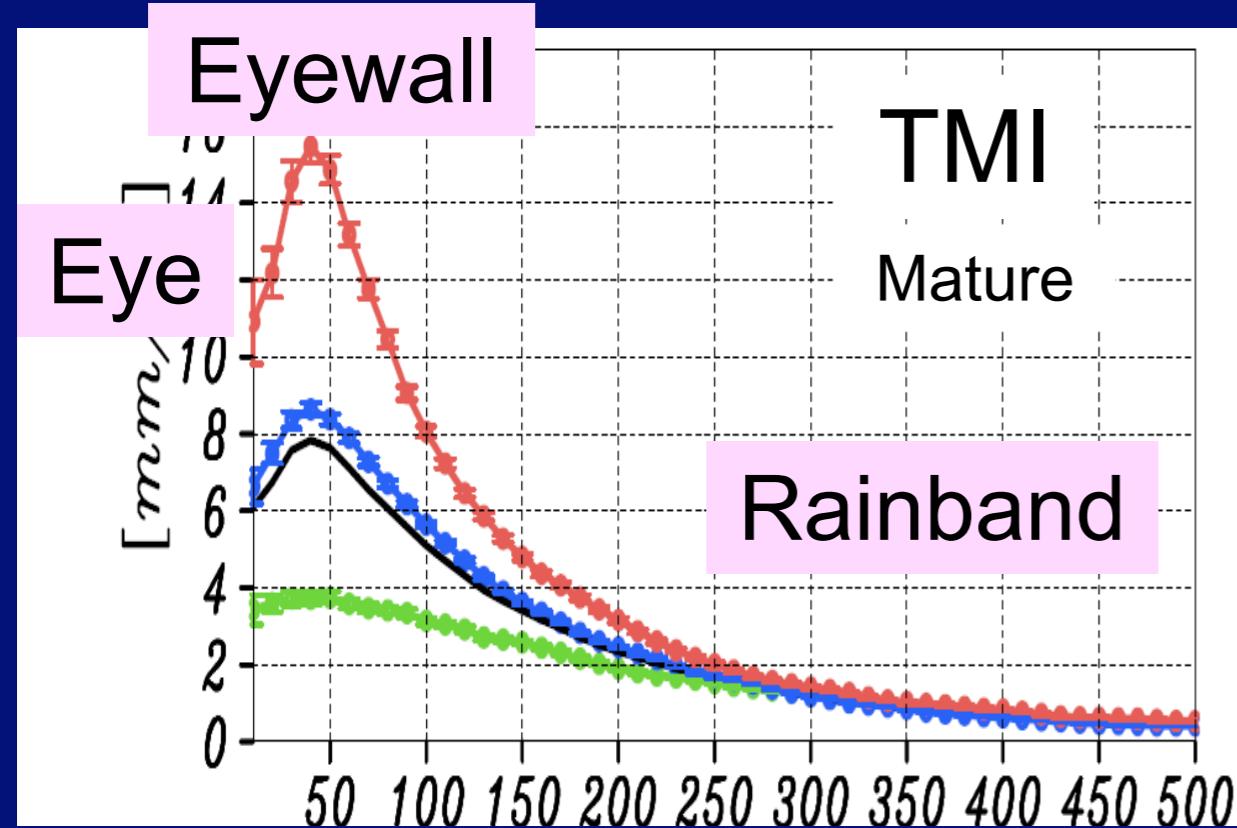
TMI-rain>PR-rain

Mean rain rate

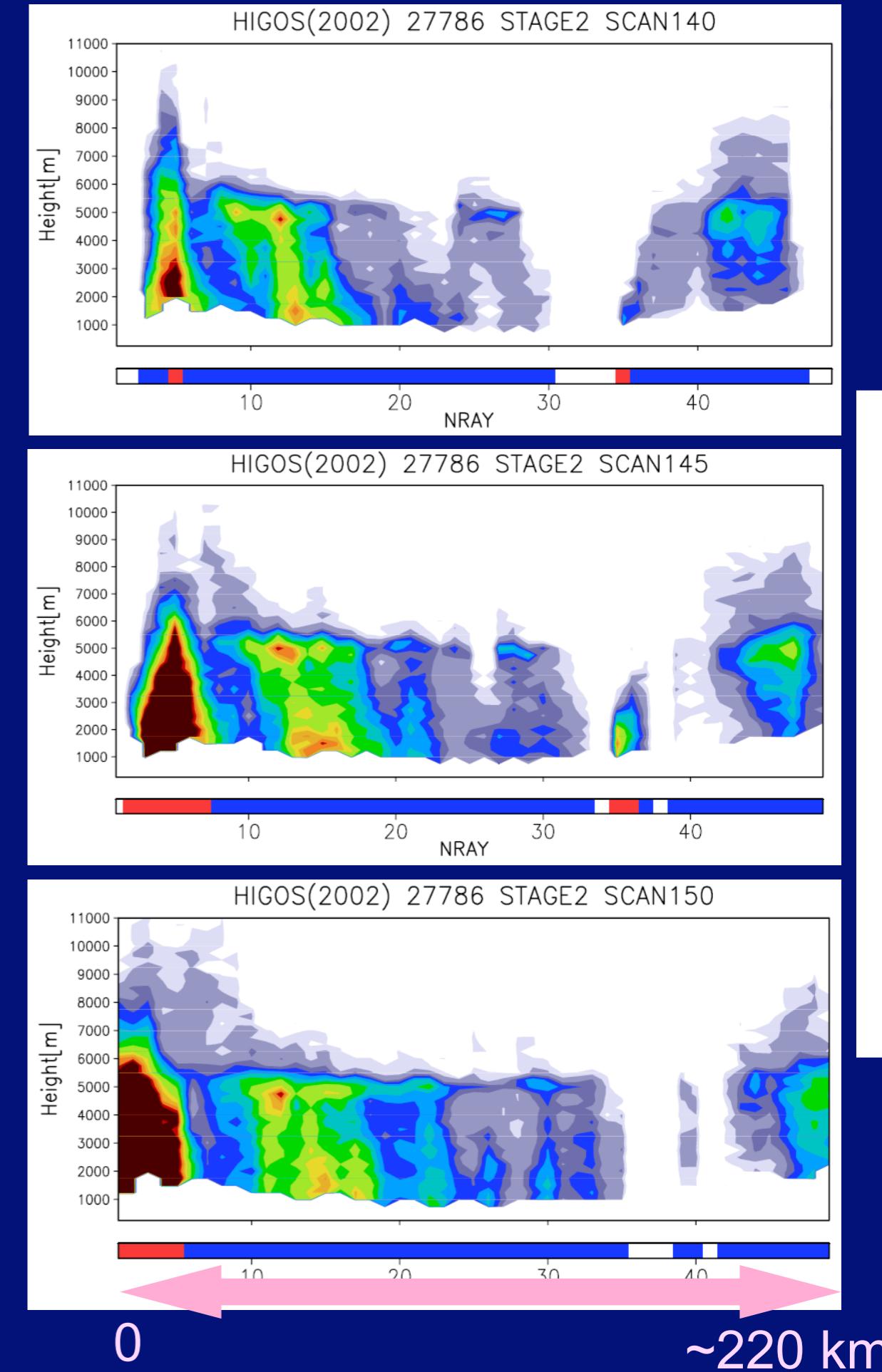
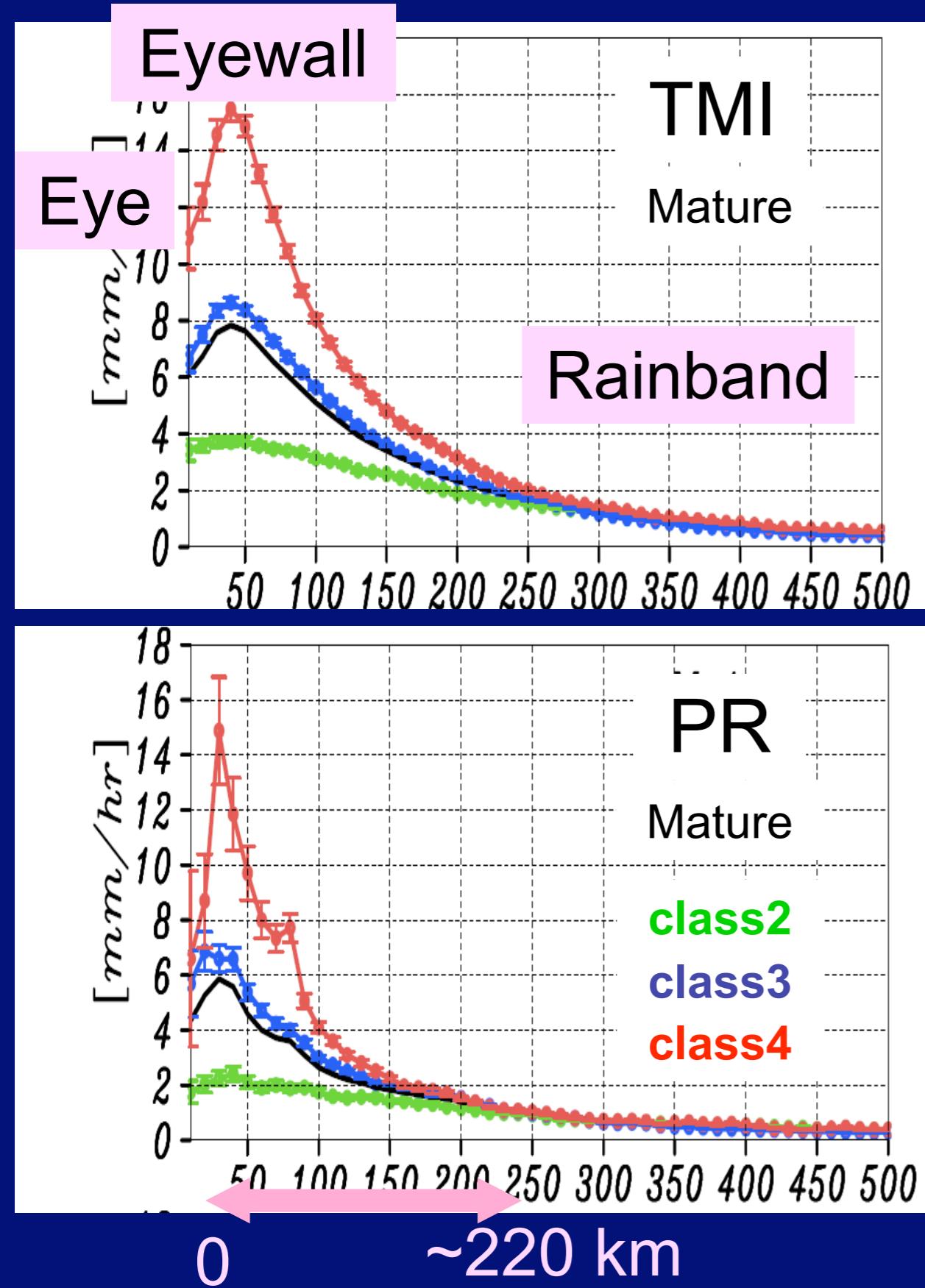


TMI-rain>PR-rain

Mean rain rate

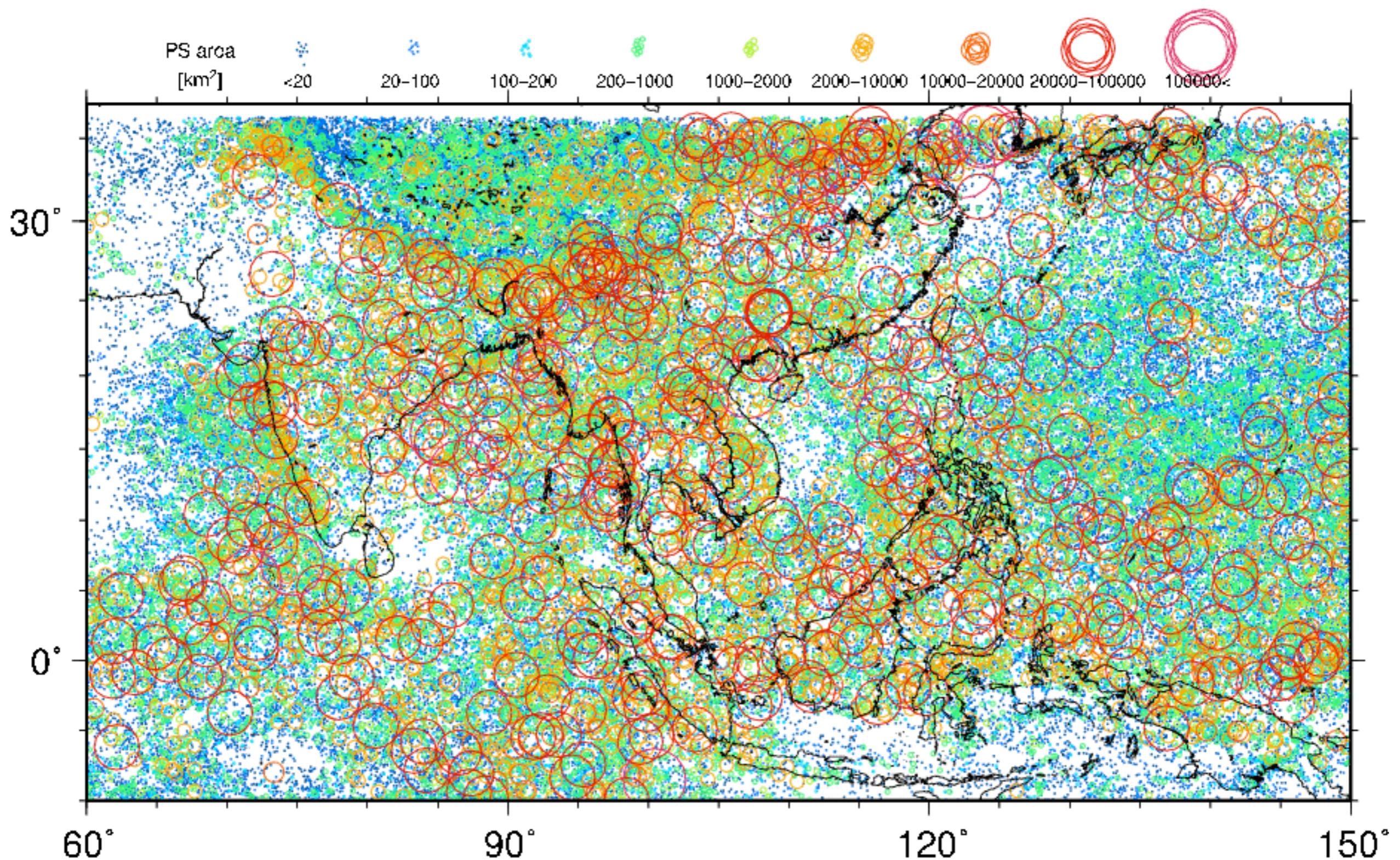


TMI-rain>PR-rain

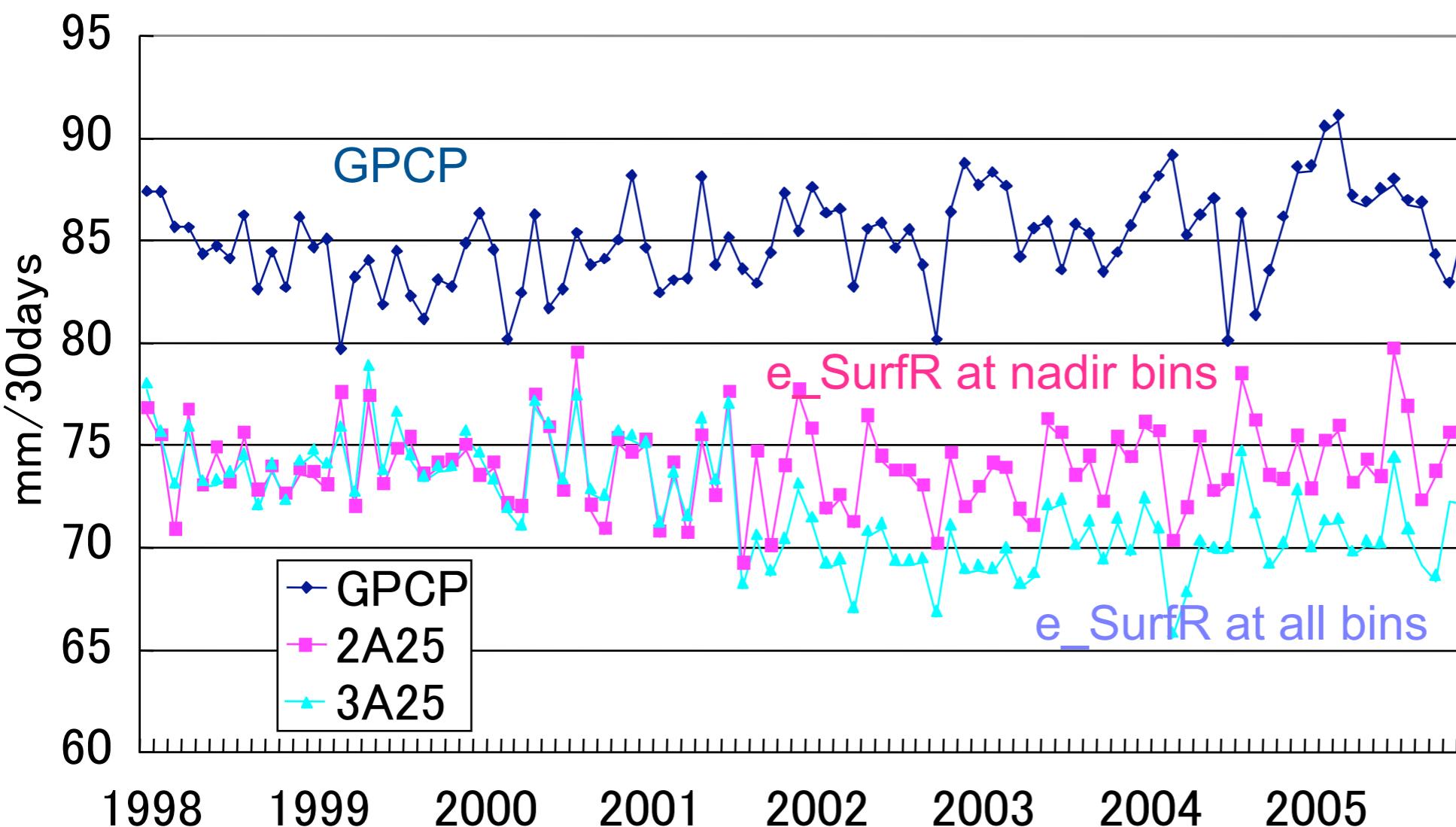


Precipitation Systems

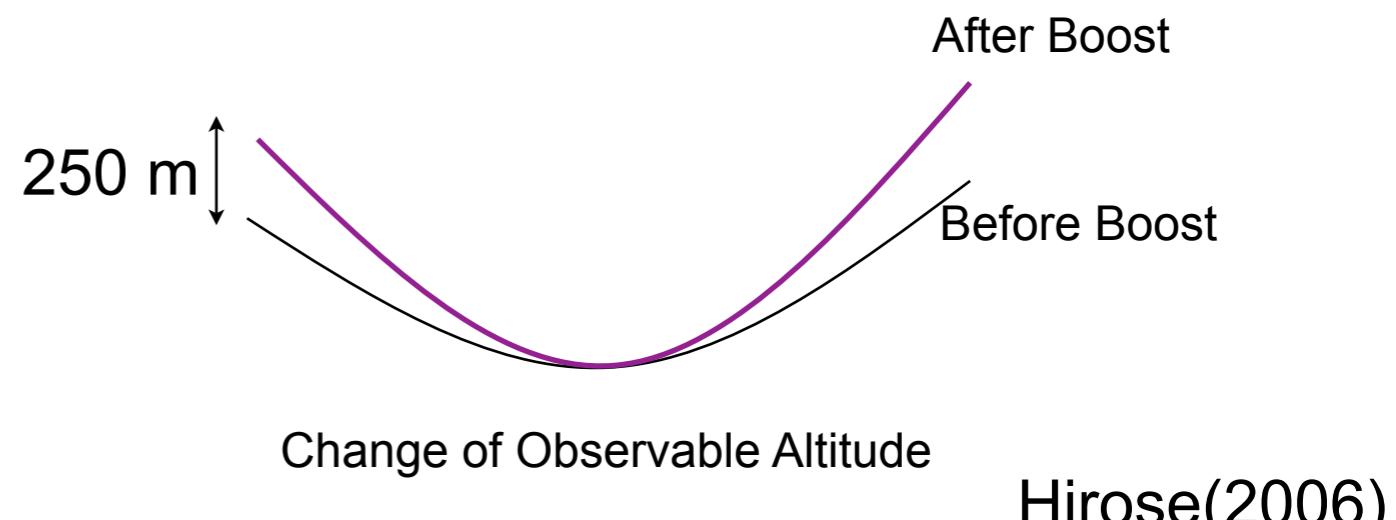
Precipitation System observed in July 2004

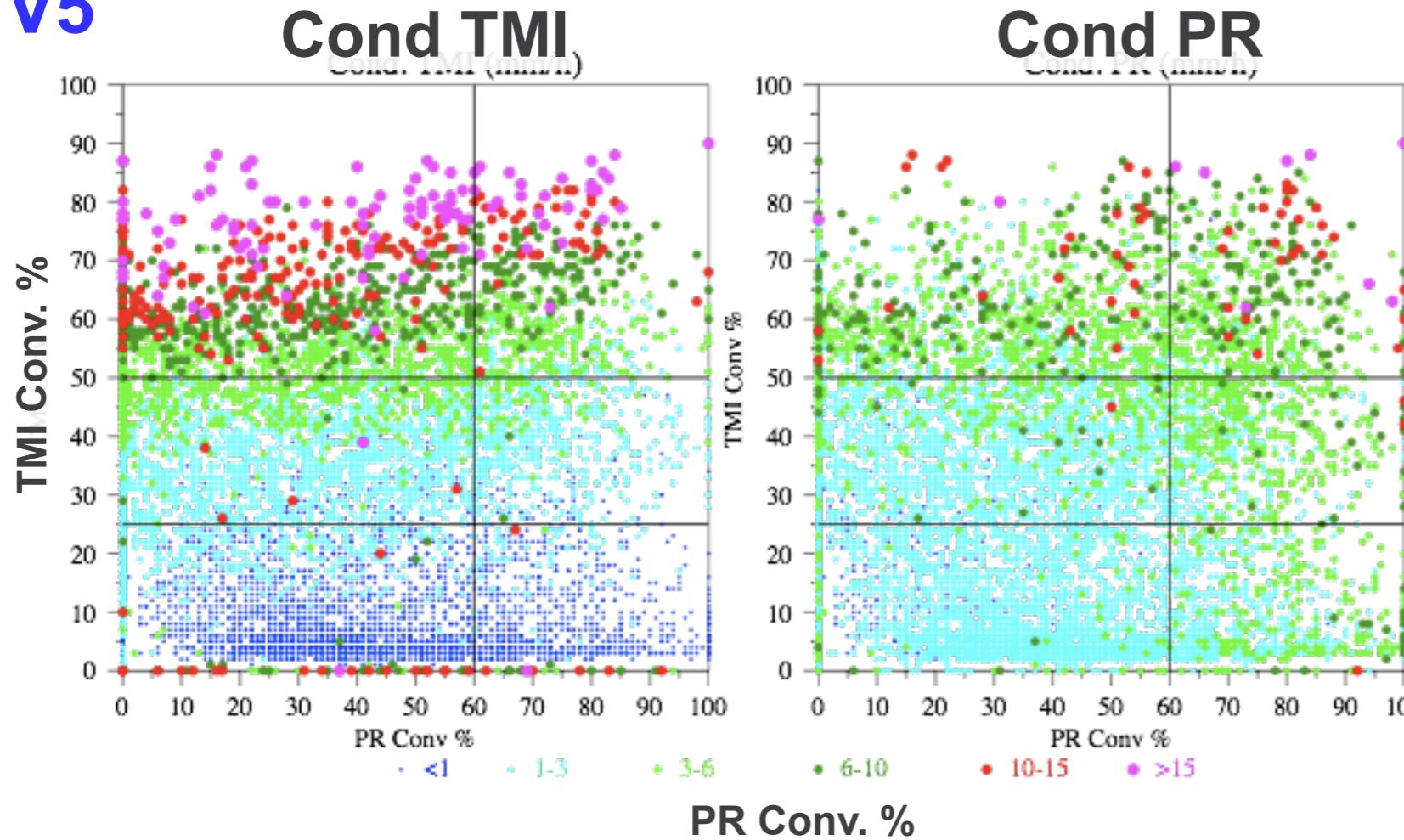


Global Monthly Total Rainfall

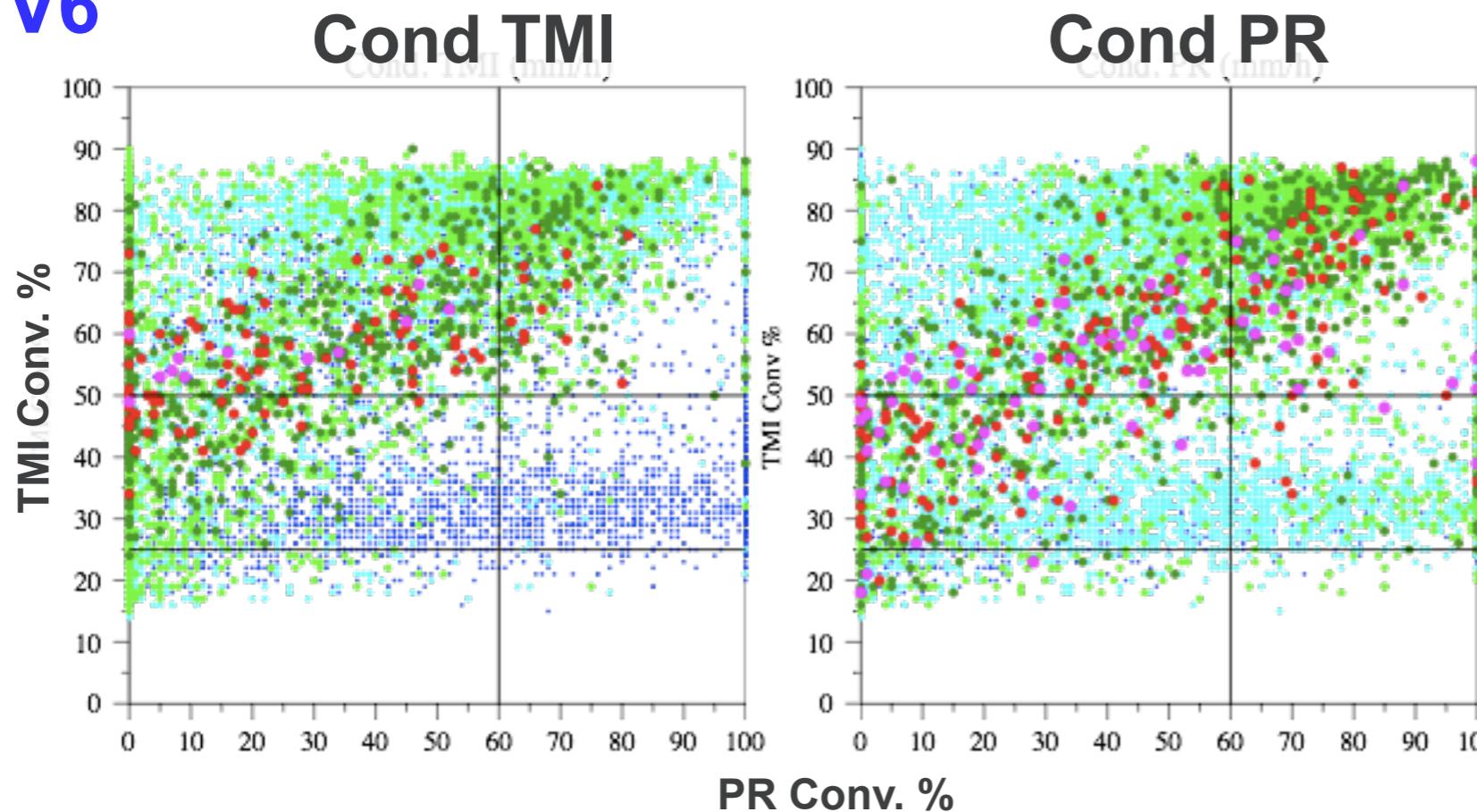


- Main Results:
- GPCP ~ 10% Greater
 - After Boost e_SurfR with all incident angles decrease by about 5 %
 - No changes of e_SurfR at nadir bins.

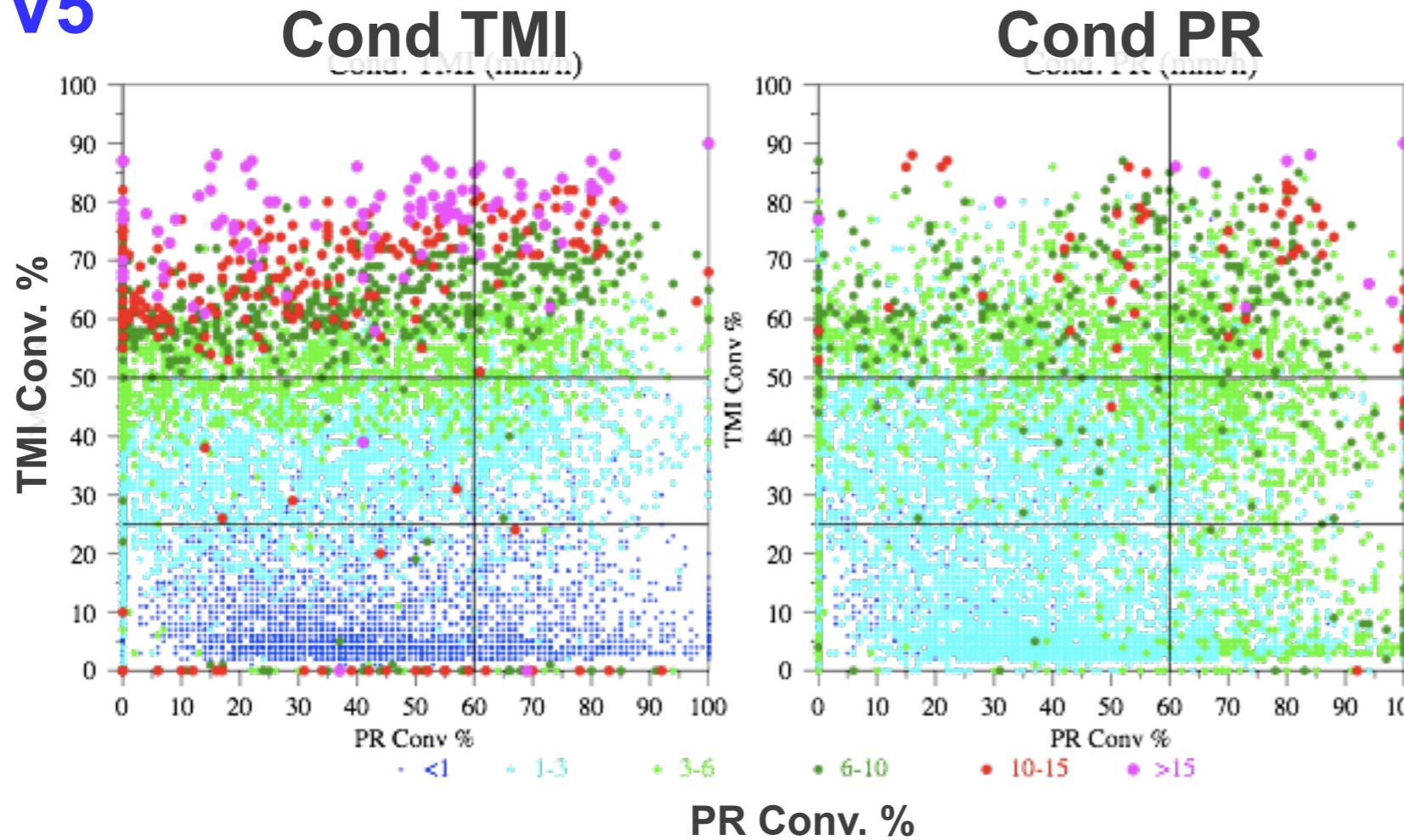


V5**Large Differences**

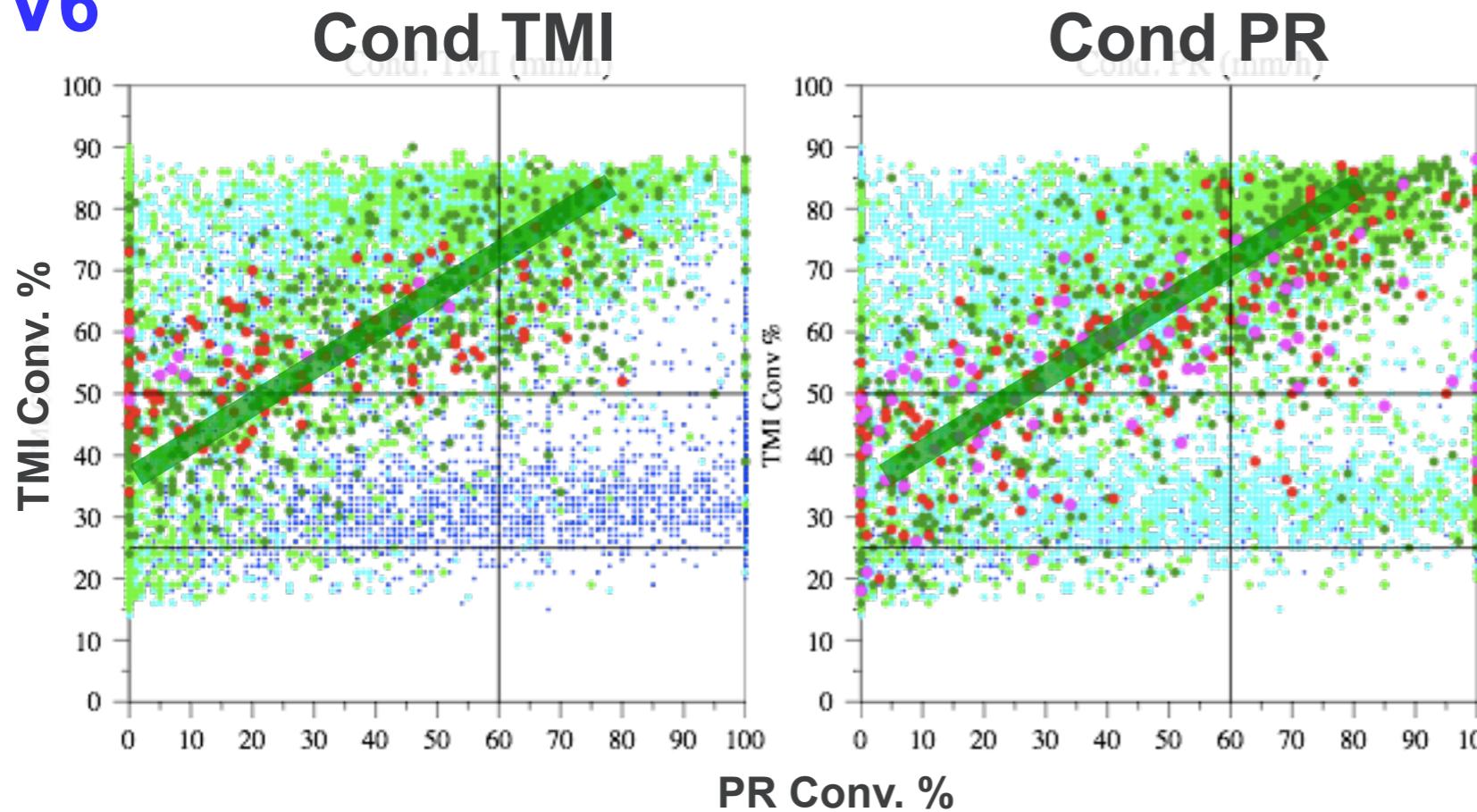
1. TMI Overestimate over Large TMI Conv. %
2. PR Overestimate over Small TMI Conv. %

V6**Both have Similar Clustering but**

1. No lower TMI Conv. %, below 15 %
2. PR Overestimate over Small TMI Conv. %

V5**Large Differences**

1. TMI Overestimate over Large TMI Conv. %
2. PR Overestimate over Small TMI Conv. %

V6**Both have Similar Clustering but**

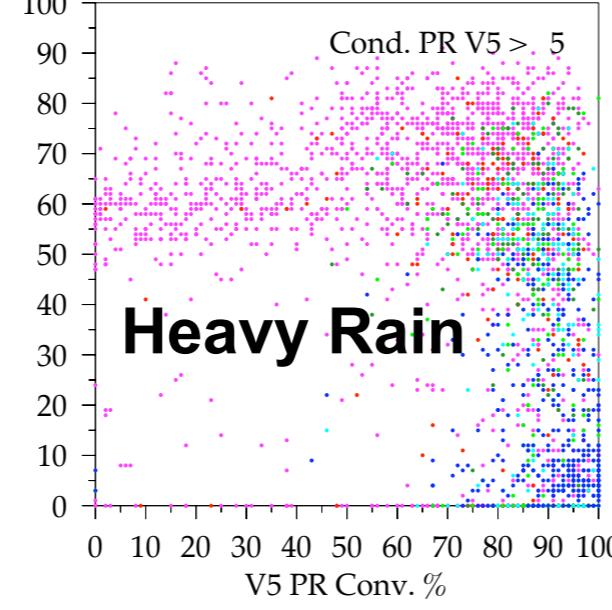
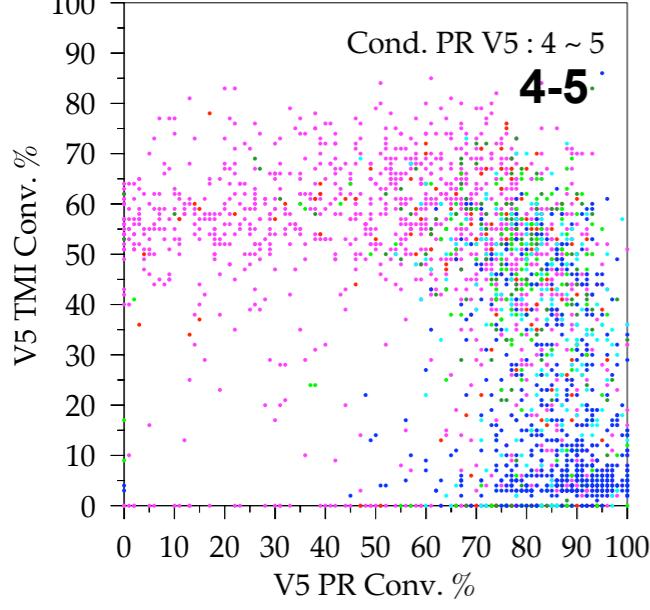
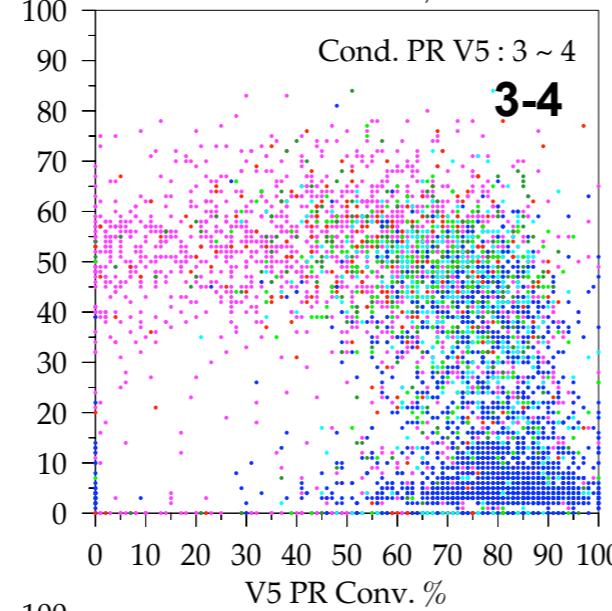
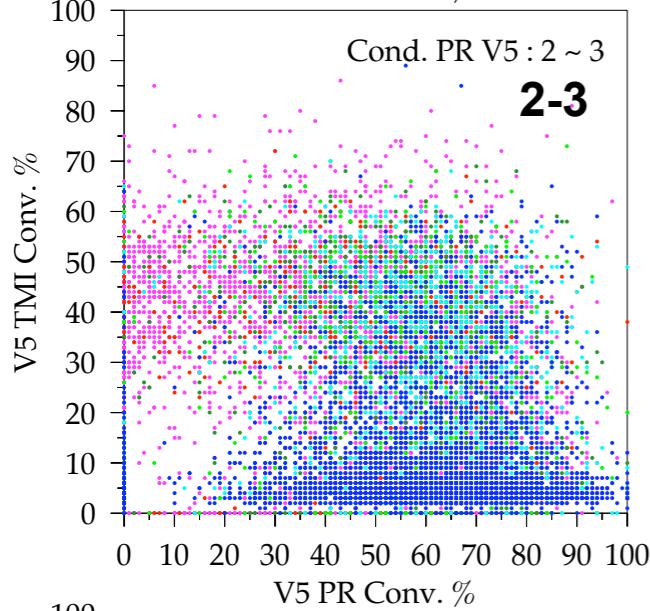
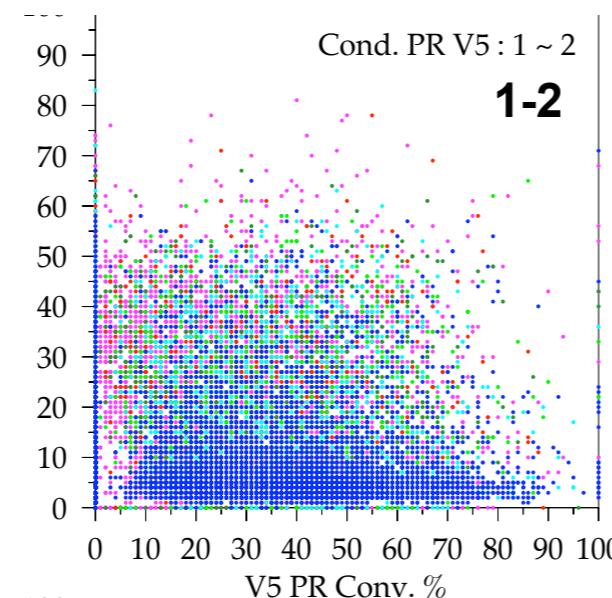
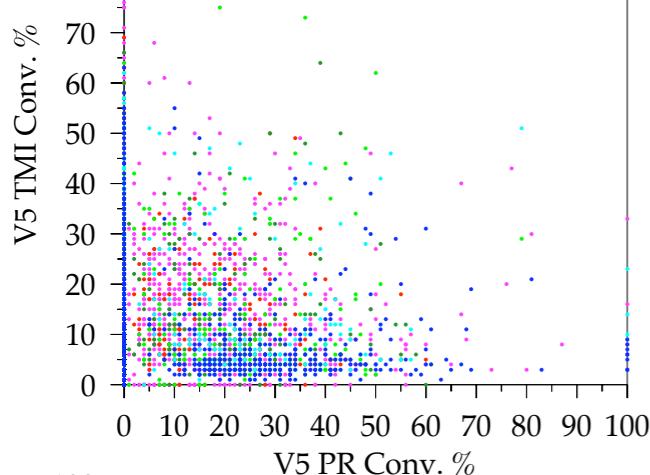
1. No lower TMI Conv. %, below 15 %
2. PR Overestimate over Small TMI Conv. %

VIRS TBB

Unconditional PR

Light Rain

Cond. PR V5 < 1
<1 mm/h



Tb ● < 240 ● 240 - 250 ● 250 - 260 ● 260 - 270 ● 270 - 280 ● 280 <

Cond. PR V5 < 1

Cond. PR V5 : 1 ~ 2

Cond. PR V5 : 2 ~ 3

Cond. PR V5 : 3 ~ 4

Cond. PR V5 : 4 ~ 5

Cond. PR V5 > 5

Ucond ● < 0.05 ● 0.05 - 0.1 ● 0.1 - 0.2 ● 0.2 - 0.5 ● 0.5 - 1.5 ● 1.5 <

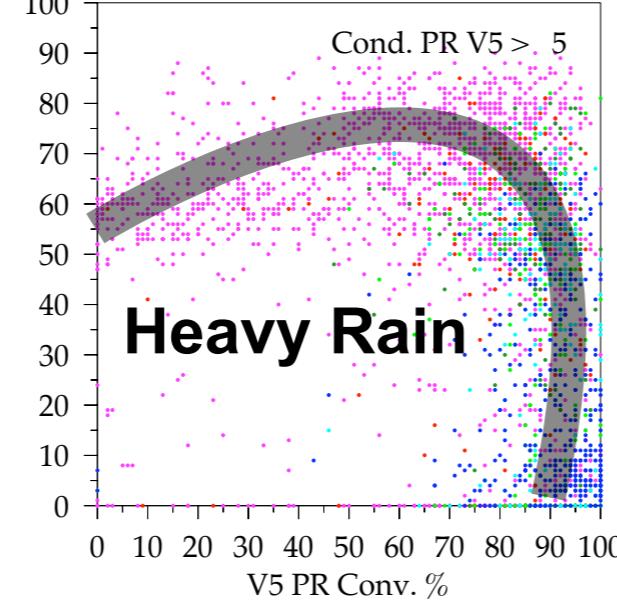
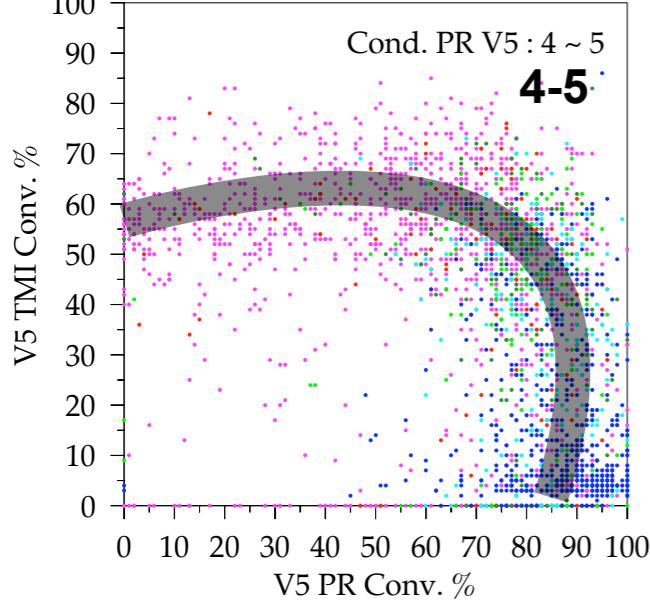
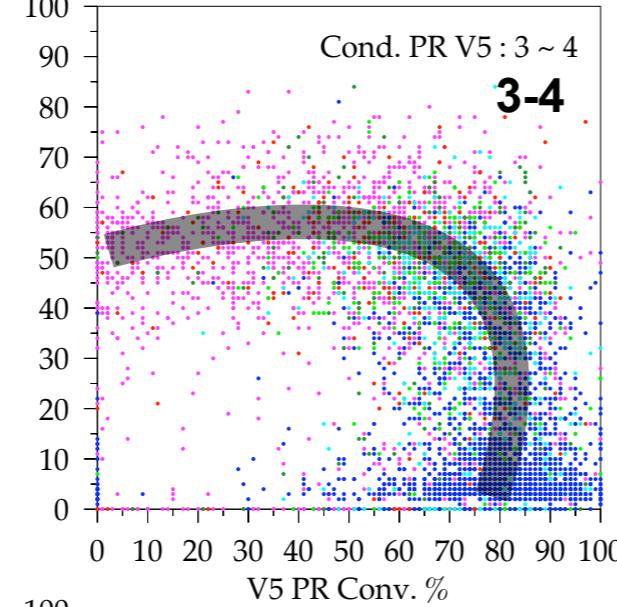
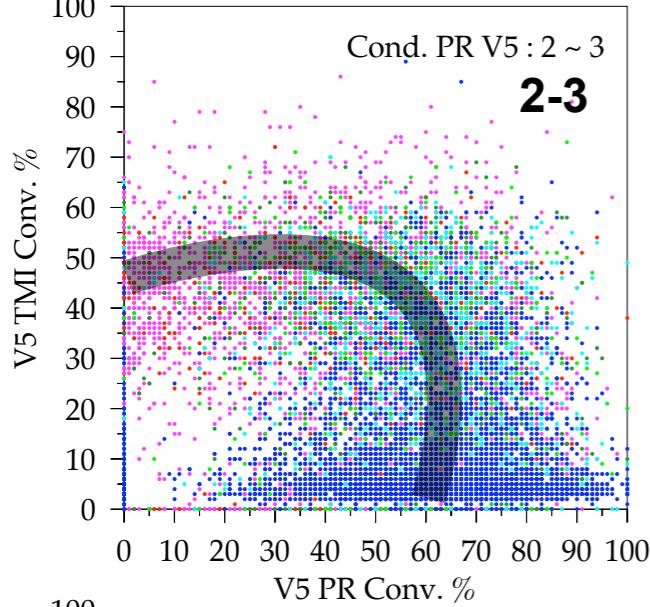
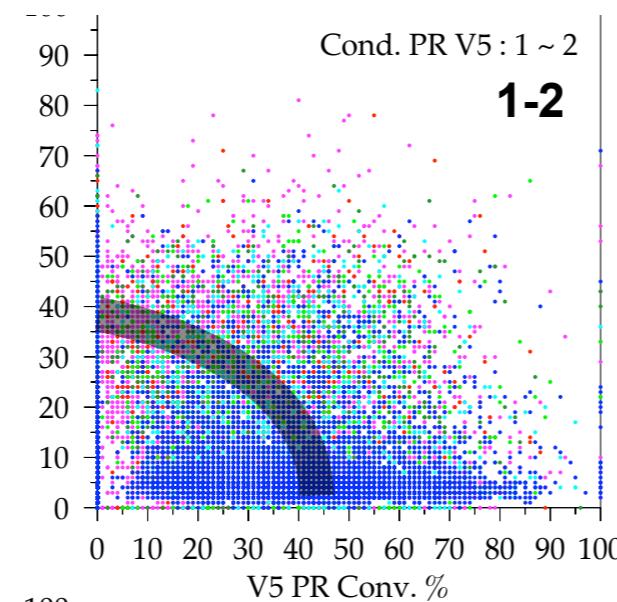
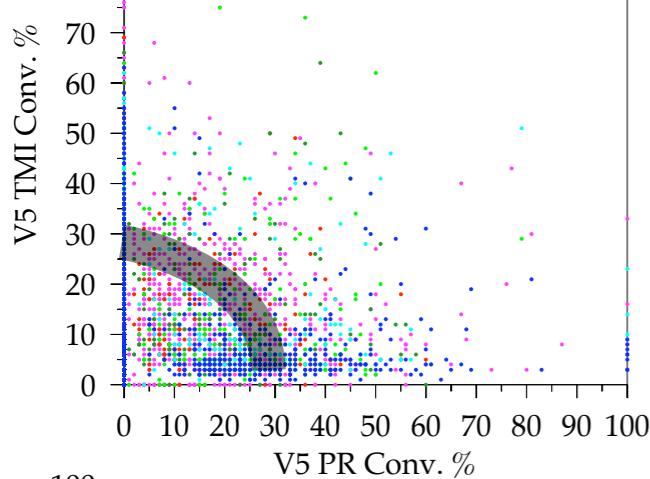
Heavy Rain

VIRS TBB

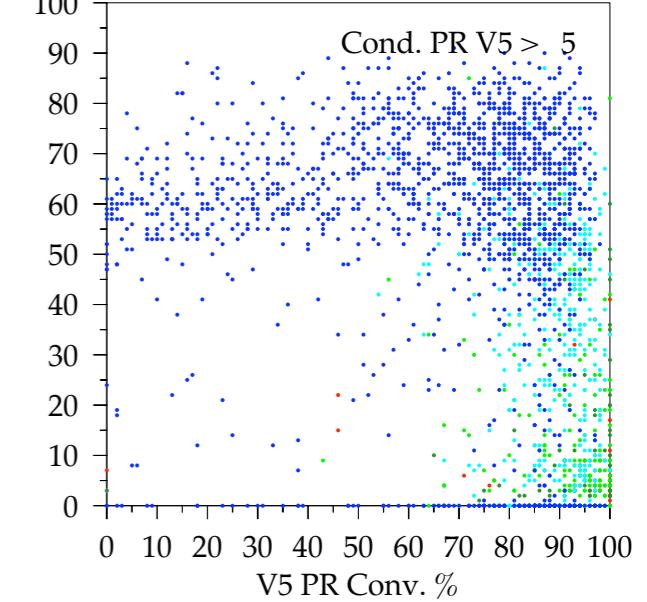
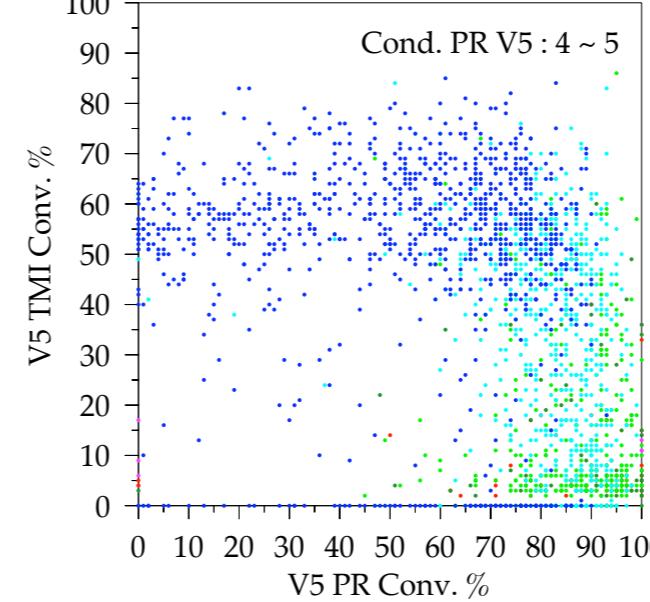
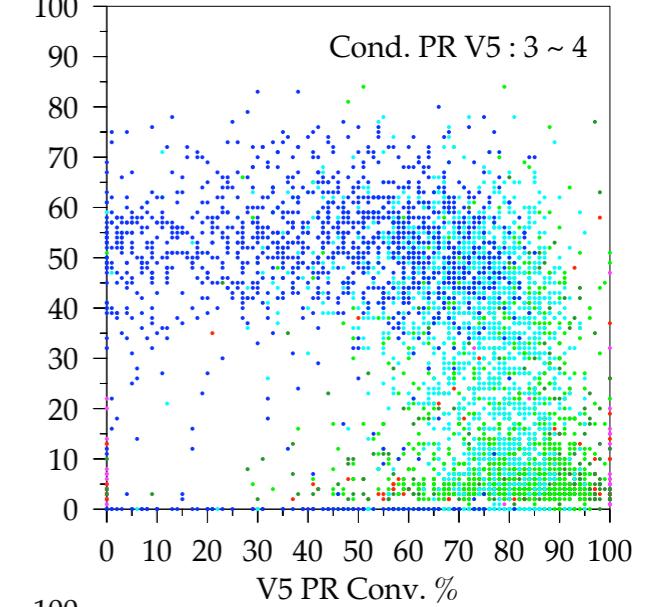
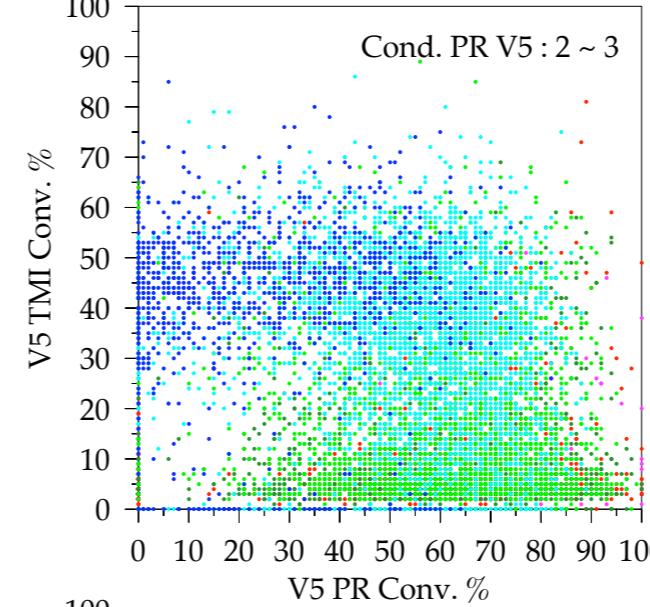
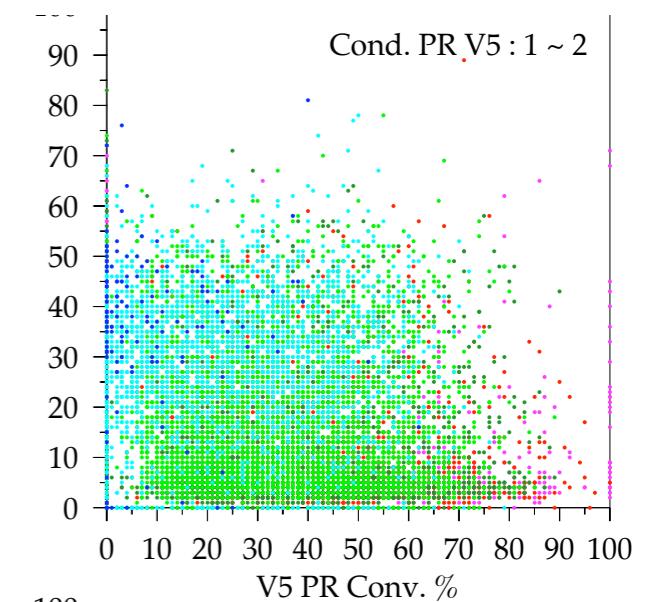
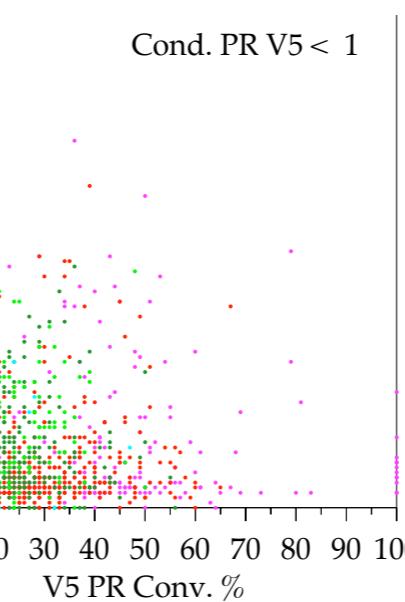
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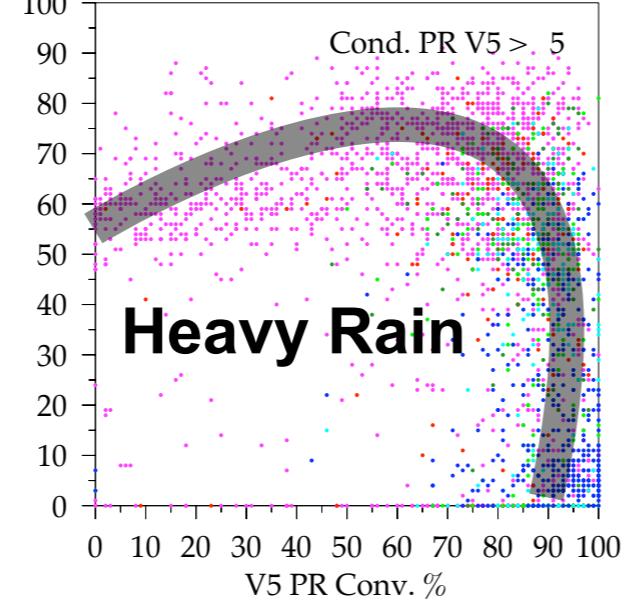
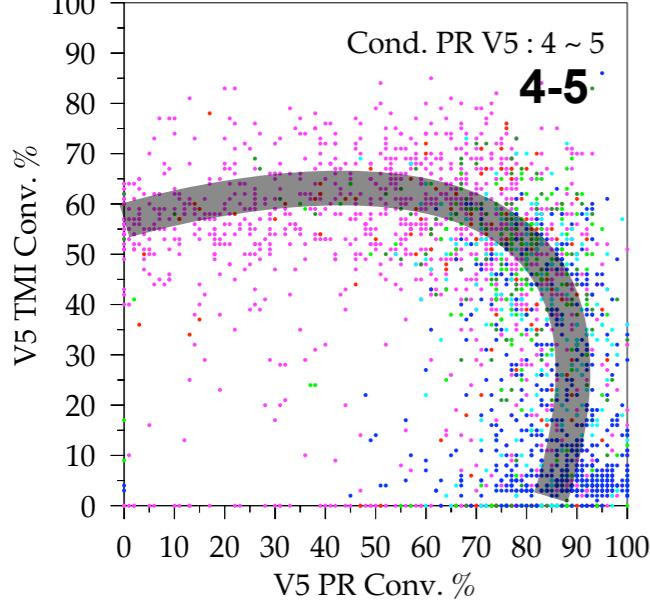
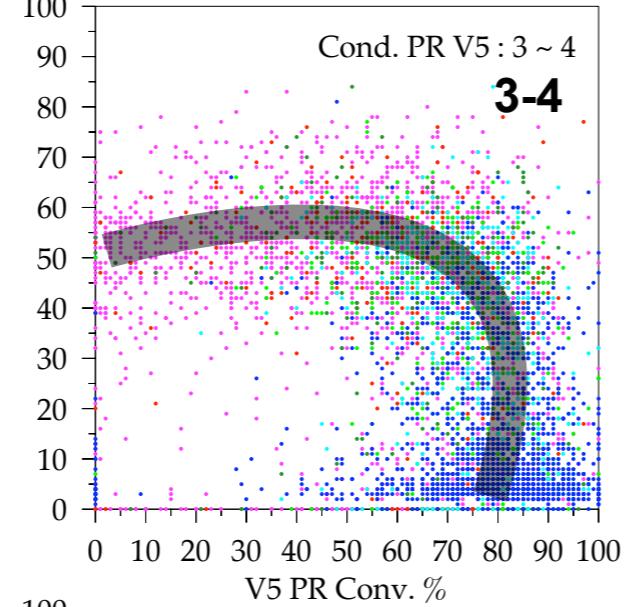
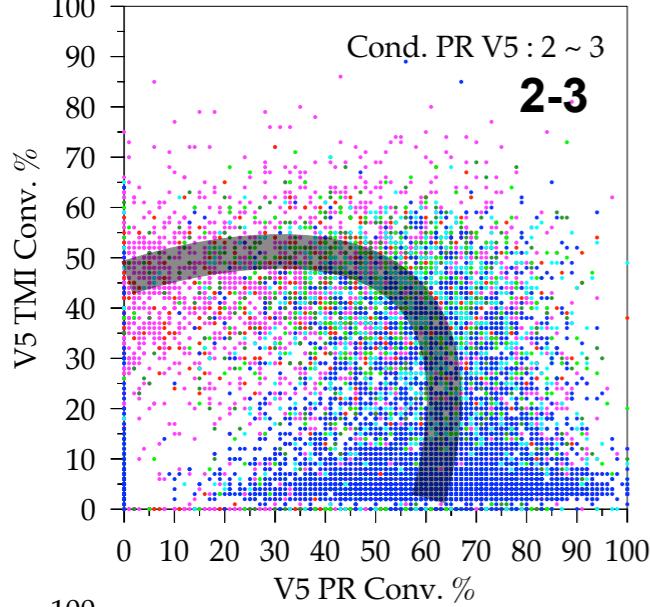
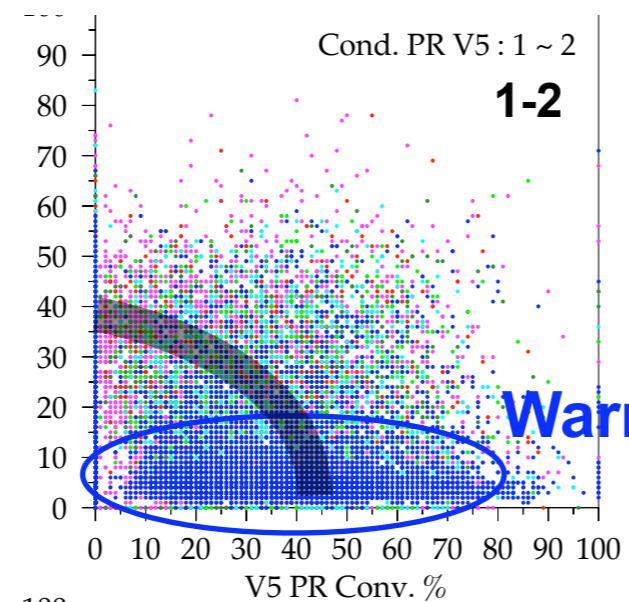
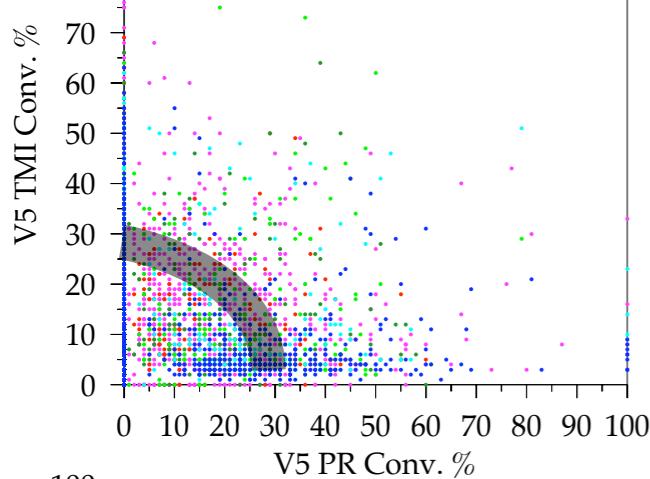
Ucond ● < 0.05 ● 0.05 - 0.1 ● 0.1 - 0.2 ● 0.2 - 0.5 ● 0.5 - 1.5 ● 1.5 <

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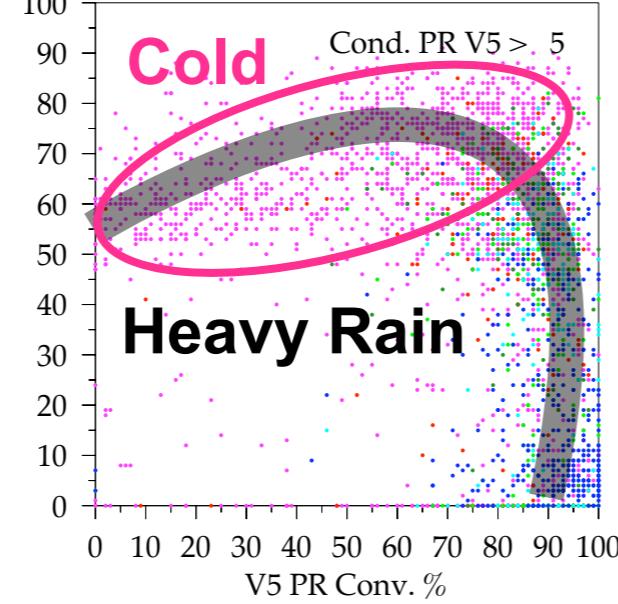
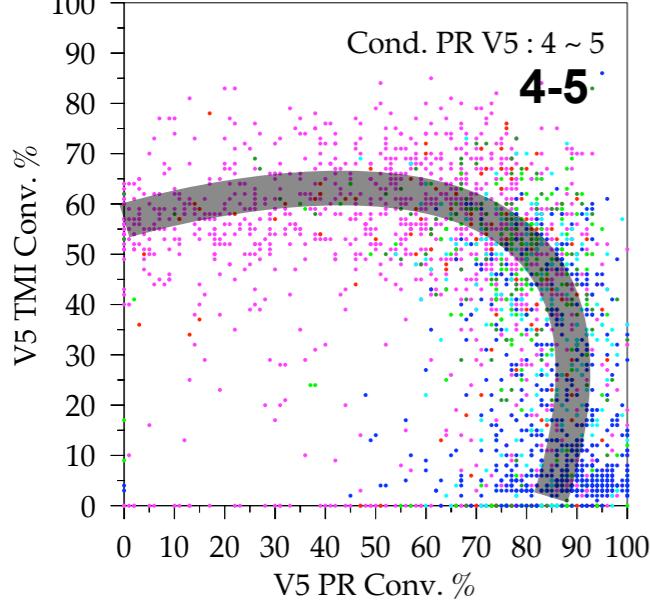
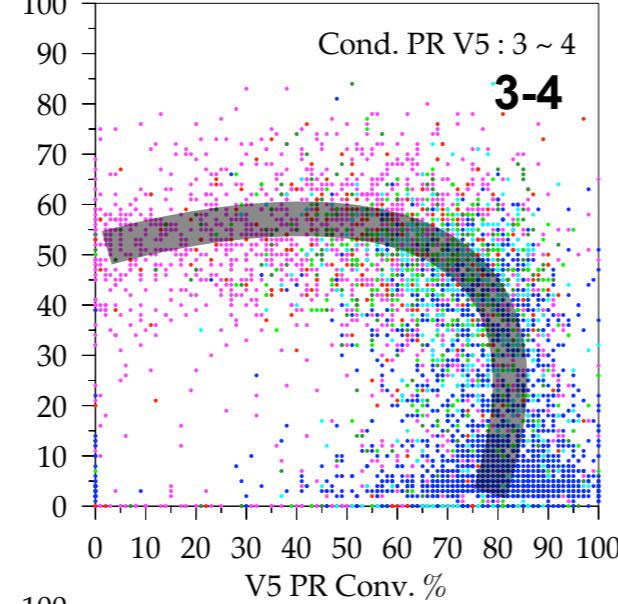
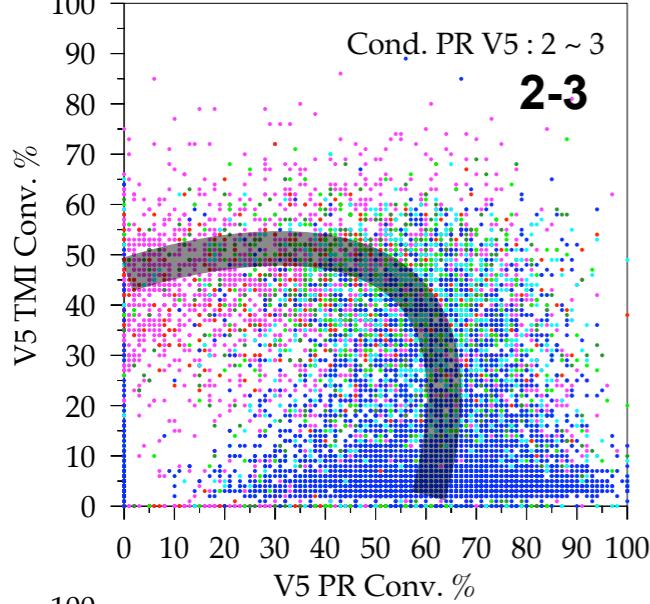
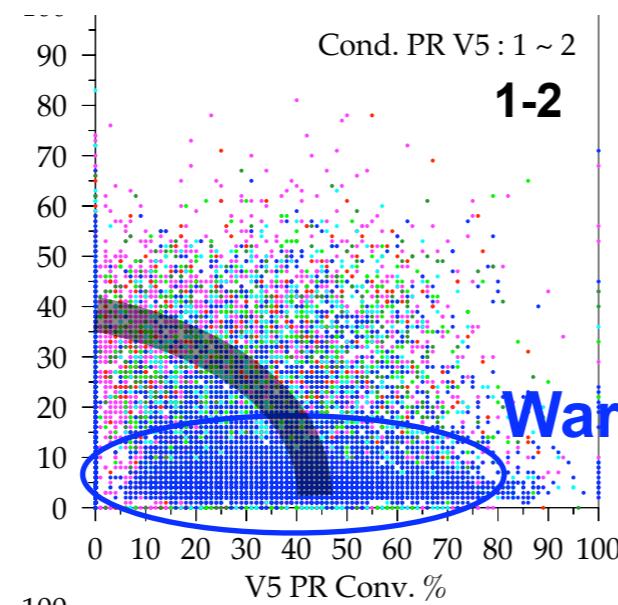
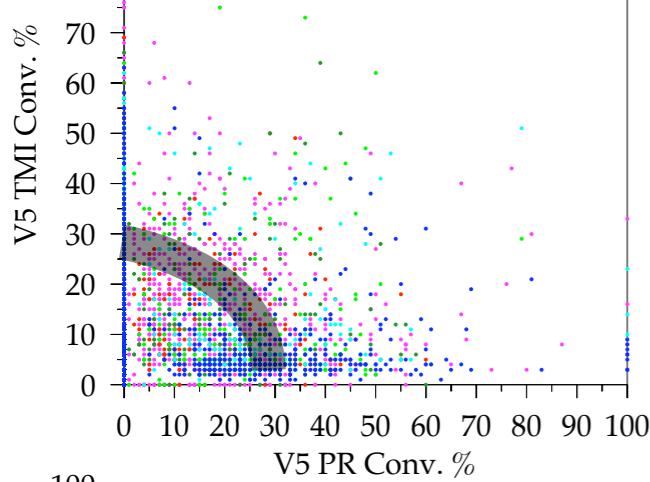
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Tb ● < 240 ● 240 - 250 ● 250 - 260 ● 260 - 270 ● 270 - 280 ● 280 <

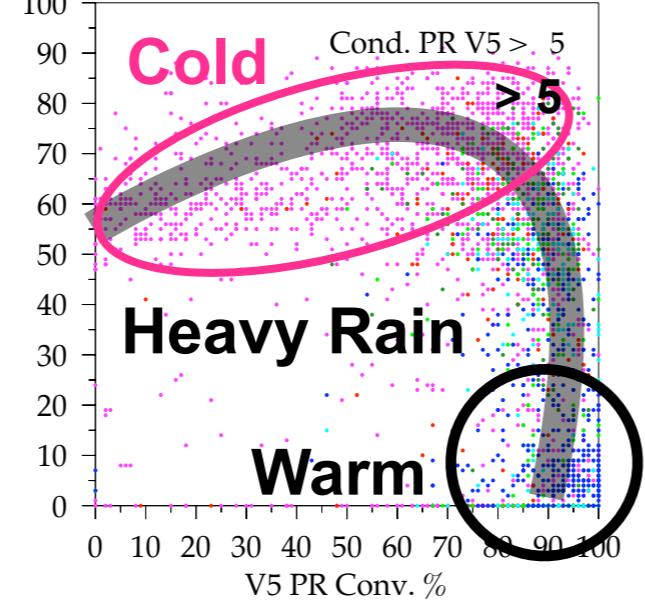
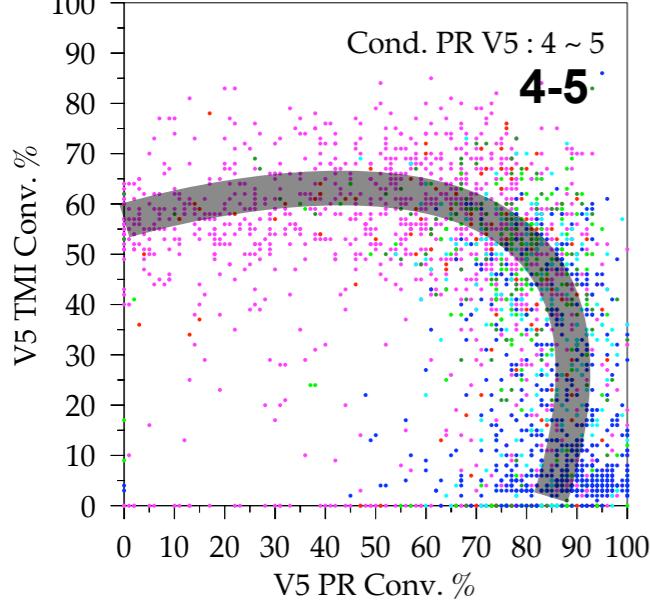
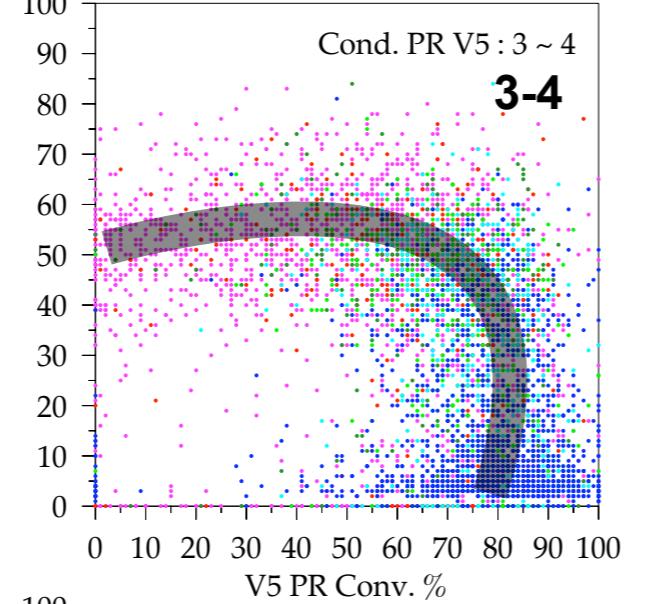
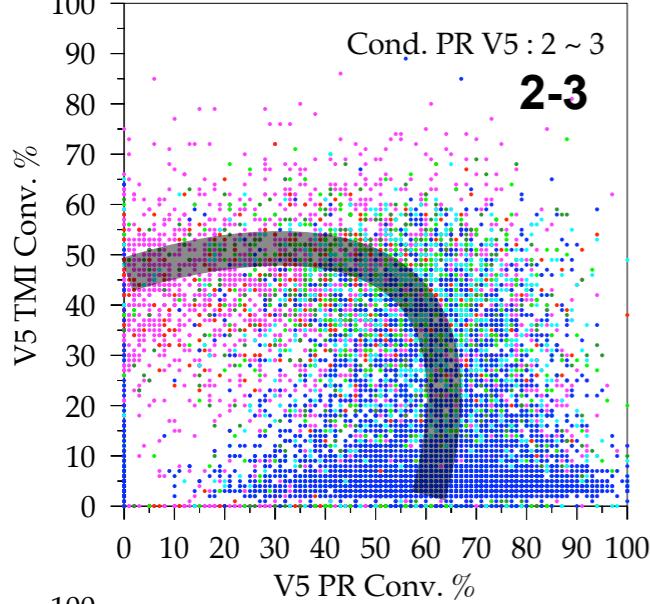
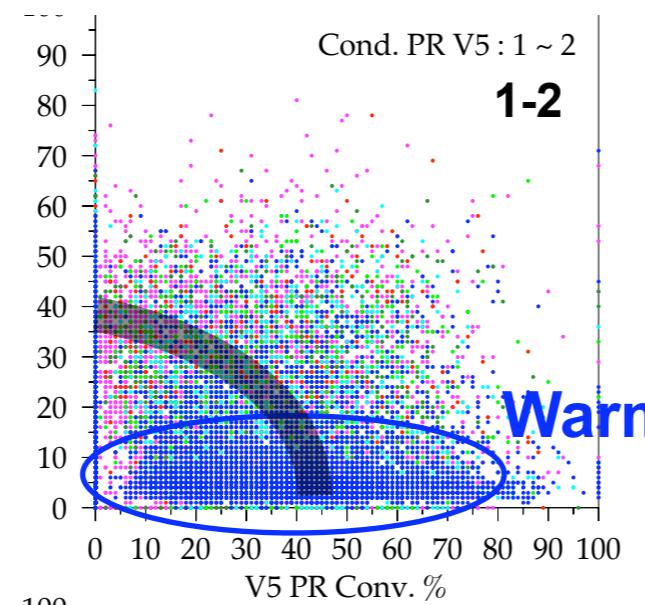
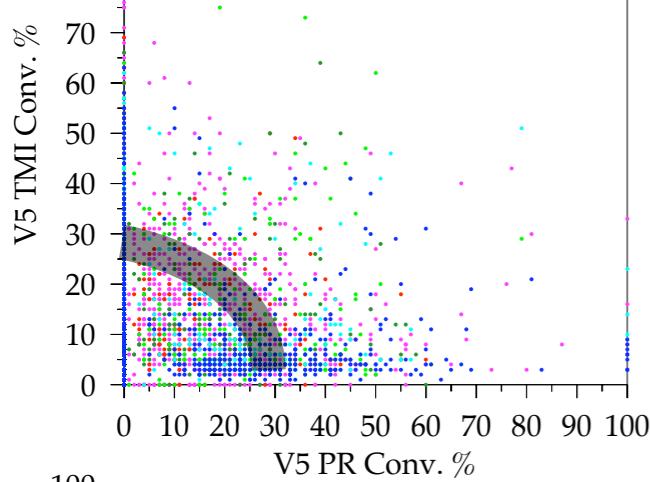
Ucond ● < 0.05 ● 0.05 - 0.1 ● 0.1 - 0.2 ● 0.2 - 0.5 ● 0.5 - 1.5 ● 1.5 <

VIRS TBB

Unconditional PR

Light Rain

Cond. PR V5 < 1
<1 mm/h

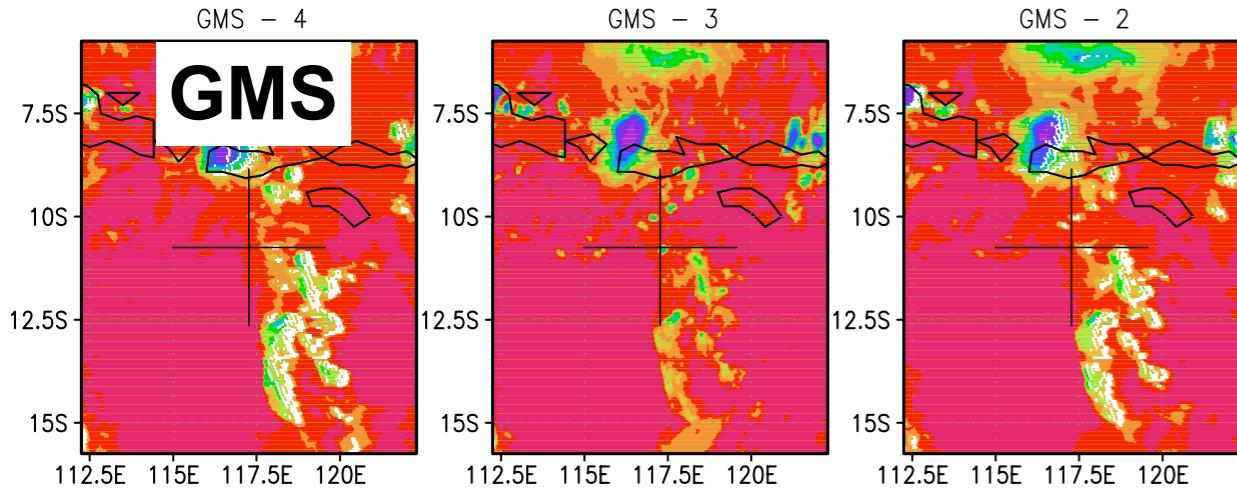


Tb ● < 240 ● 240 - 250 ● 250 - 260 ● 260 - 270 ● 270 - 280 ● 280 <

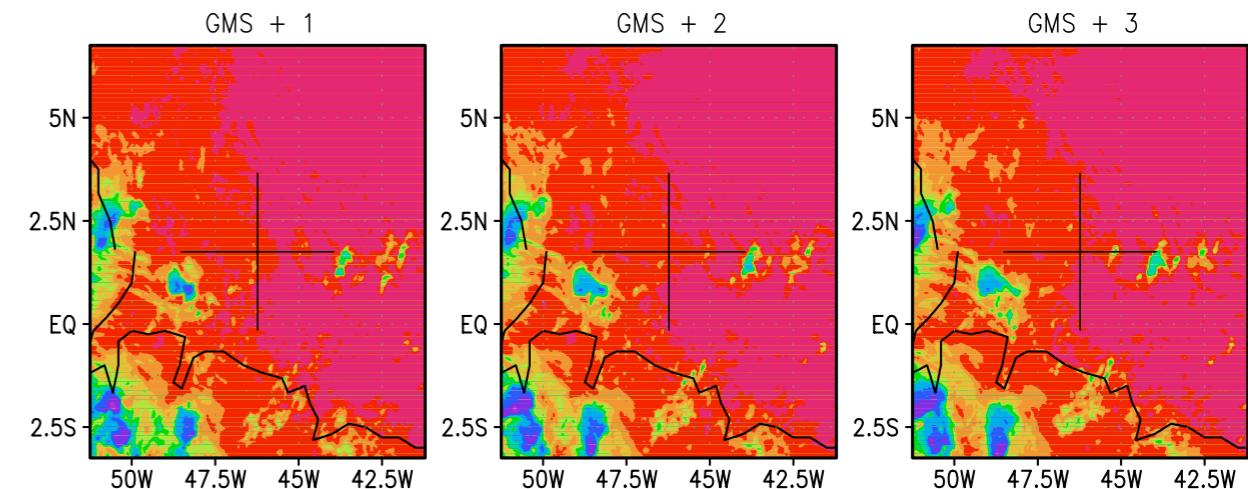
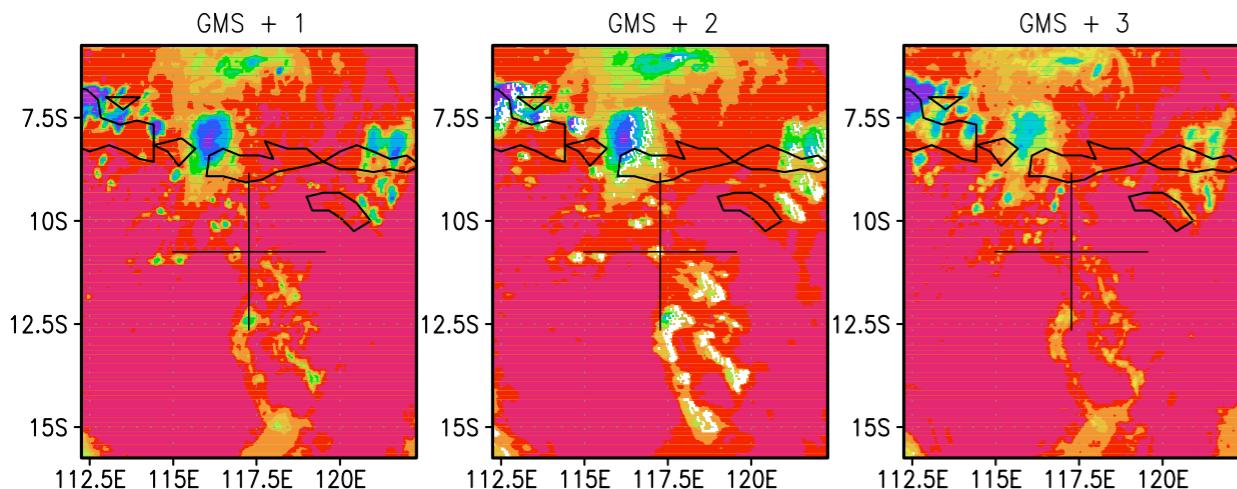
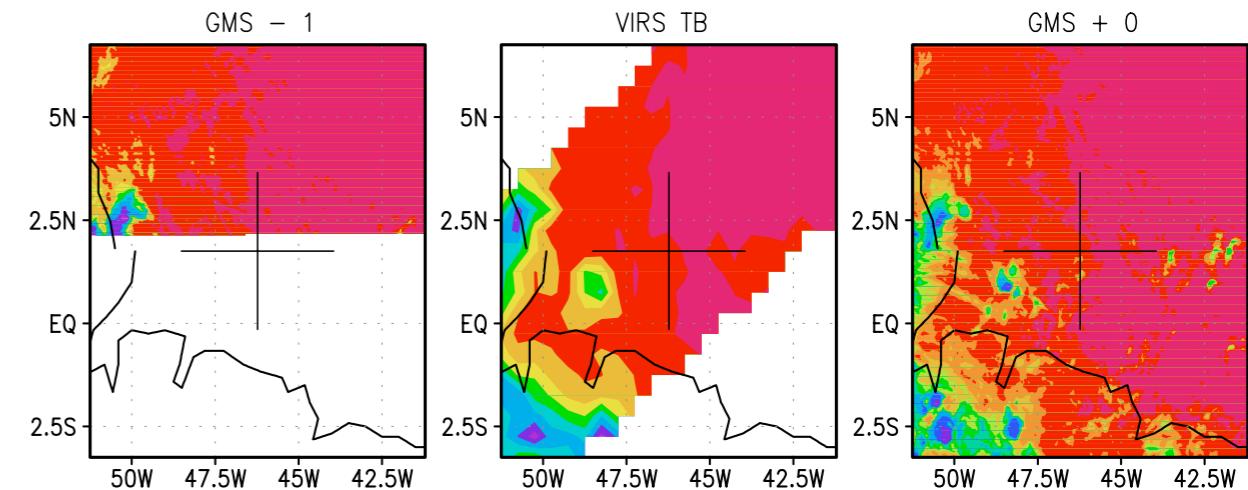
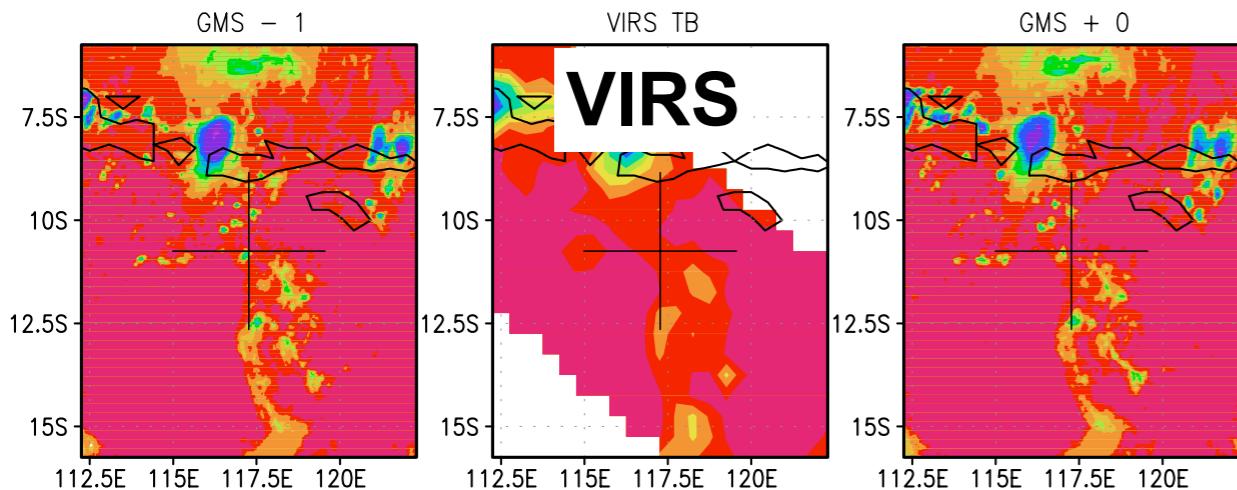
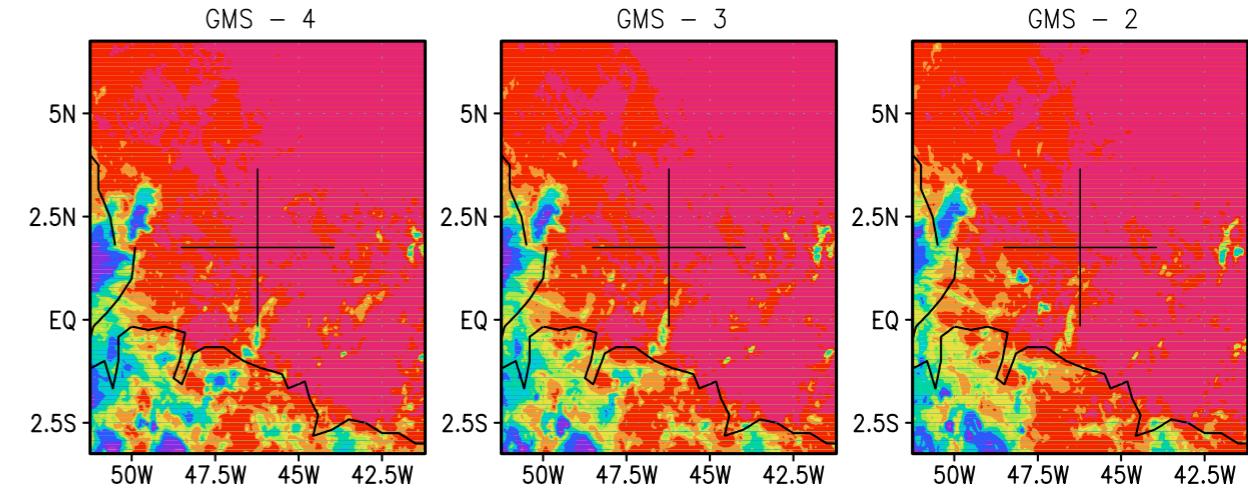
Ucond ● < 0.05 ● 0.05 - 0.1 ● 0.1 - 0.2 ● 0.2 - 0.5 ● 0.5 - 1.5 ● 1.5 <

Heavy Rcond with Warm TB

15Z30MAR2000 ~ 18:30Z30MAR2000

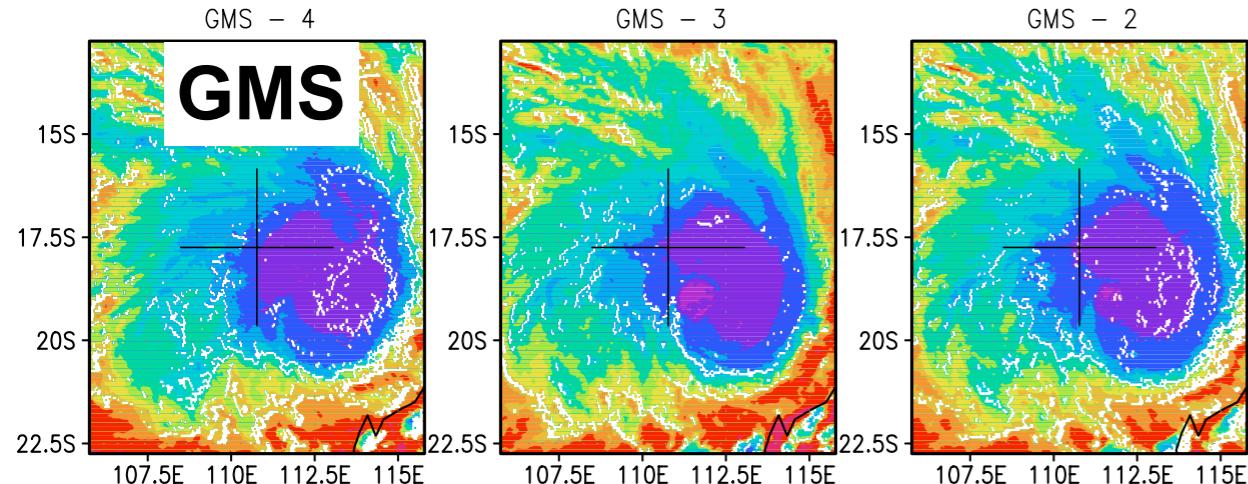


23Z11MAR2000 ~ 02:30Z12MAR2000

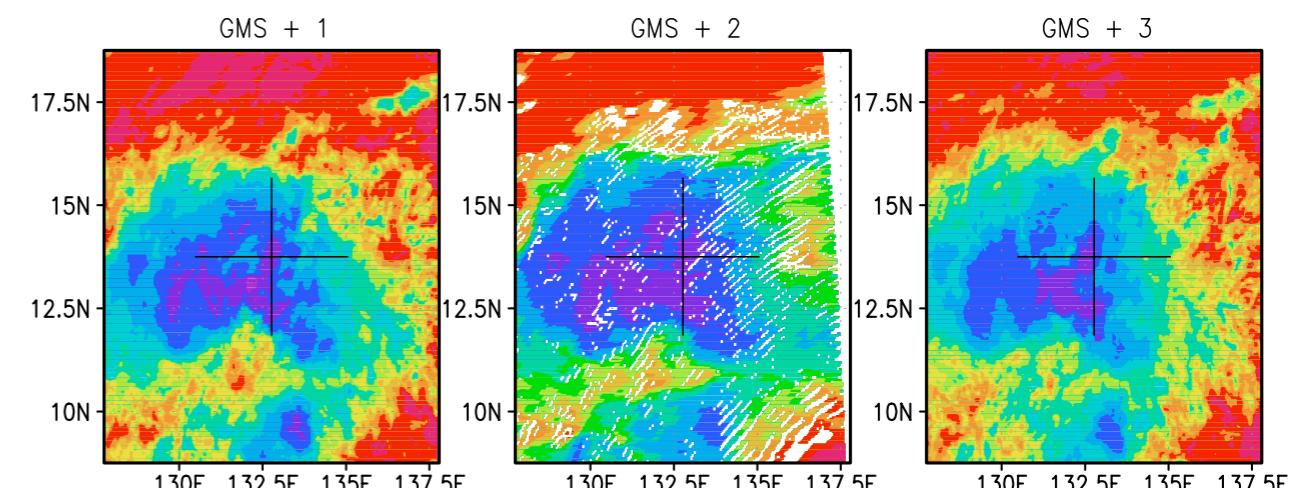
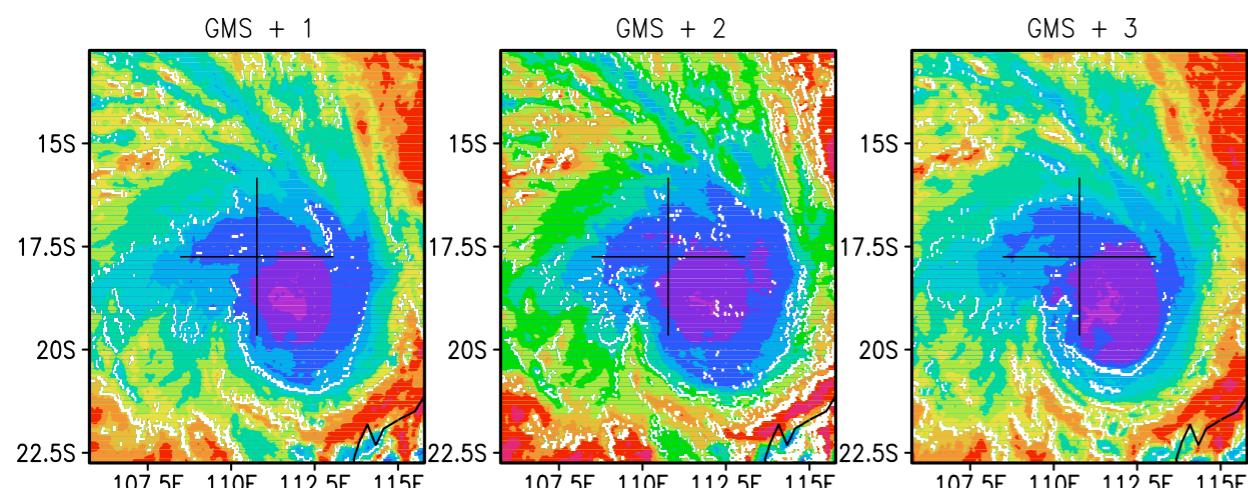
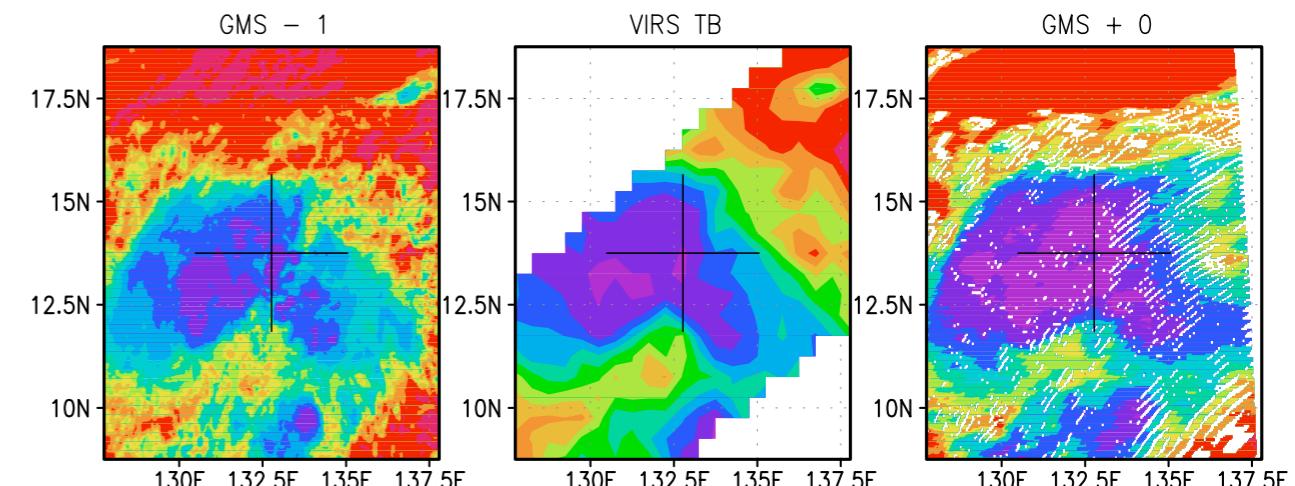
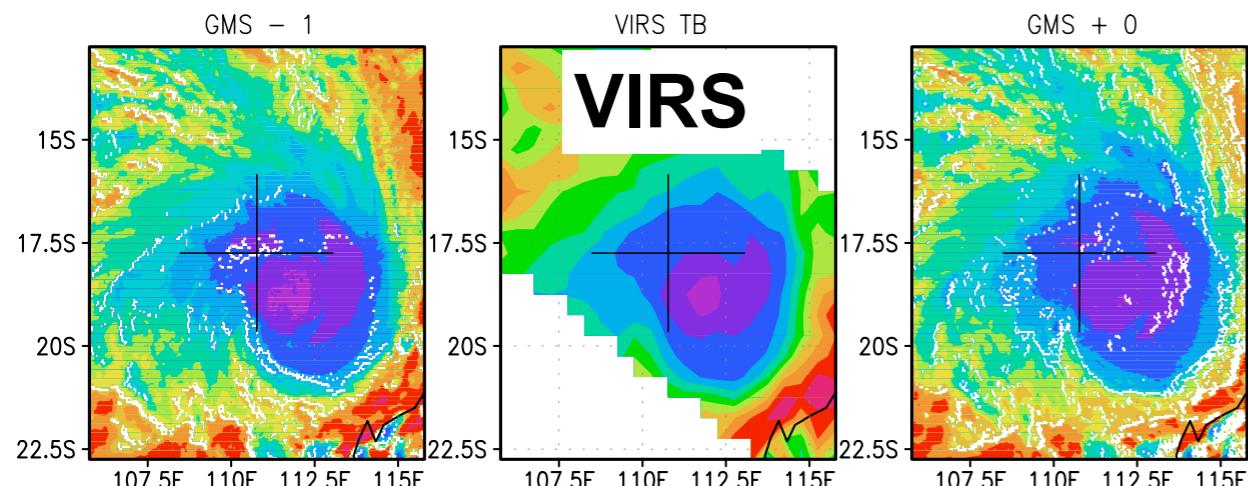
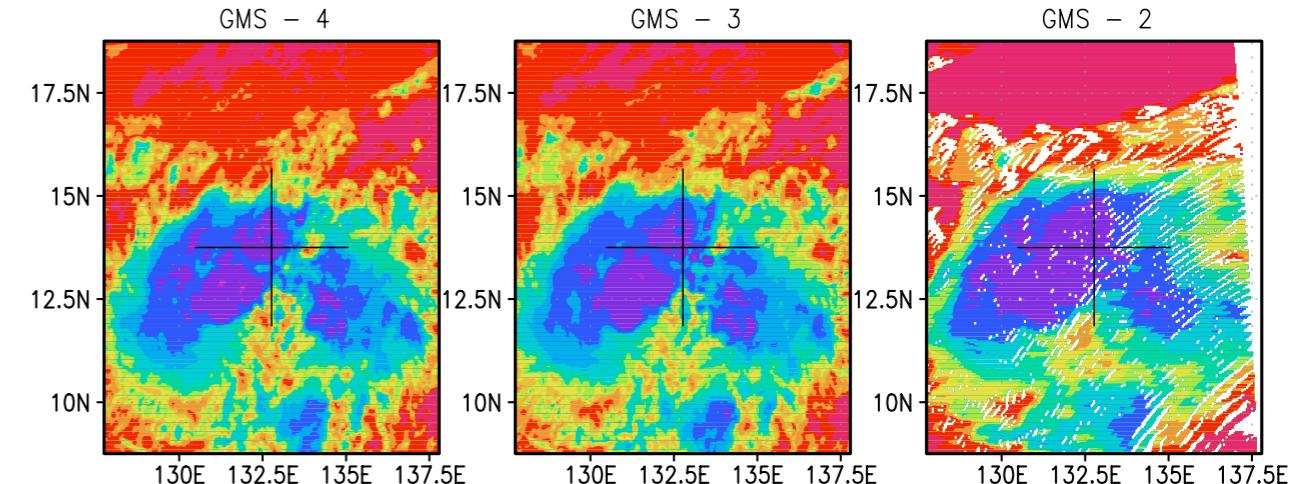


Heavy Rcond with Cold TB

07Z02MAR2000 ~ 10:30Z02MAR2000



05Z25MAR2000 ~ 08:30Z25MAR2000



190 200 210 220 230 240 250 260 270 280 290

190 200 210 220 230 240 250 260 270 280 290

Why both TMI & PR rain estimates of the same convective system are different?

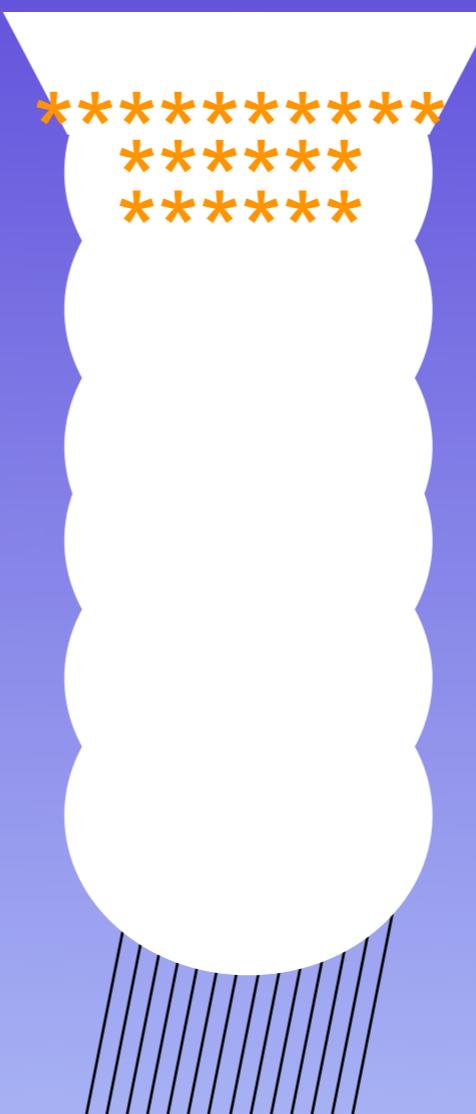
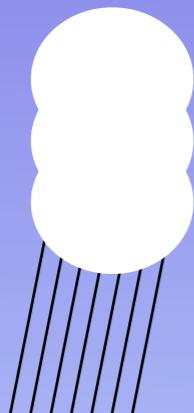
Formation/Developing Stage

Post-Mature Stage

Decaying Stage

PR > TMI

TMI > PR



Why both TMI & PR rain estimates of the same convective system are different?

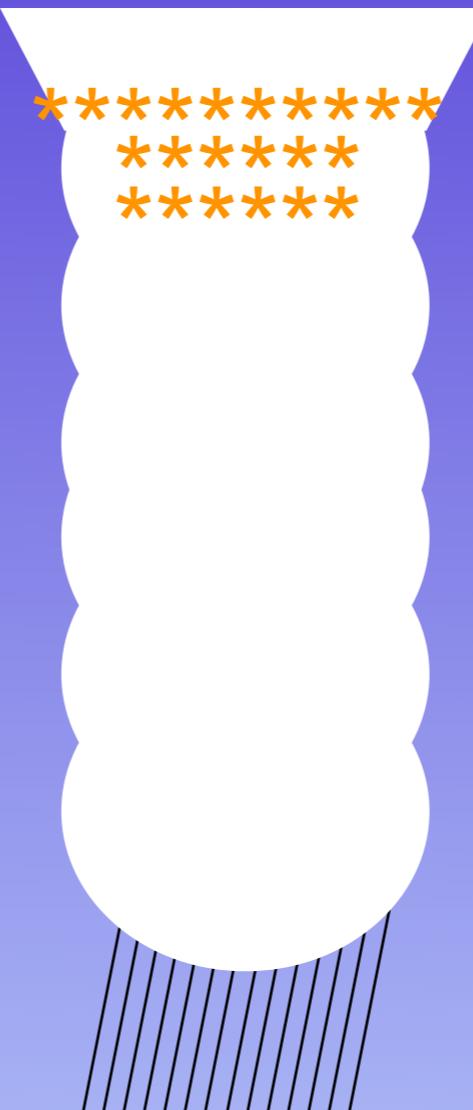
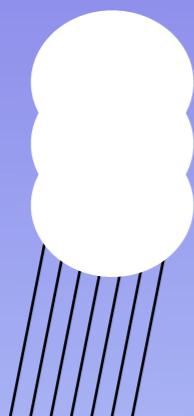
Formation/Developing Stage

Post-Mature Stage

Decaying Stage

PR > TMI

TMI > PR



TMI may underestimate due to **Larger Footprint with No Ice Scattering Signal**

Why both TMI & PR rain estimates of the same convective system are different?

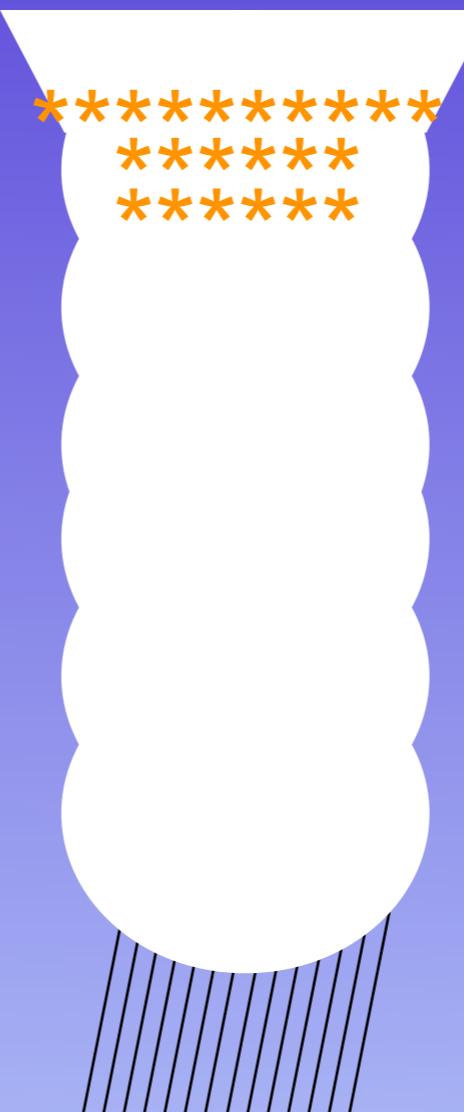
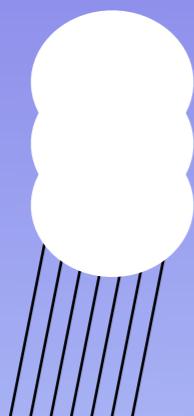
Formation/Developing Stage

Post-Mature Stage

Decaying Stage

PR > TMI

TMI > PR



TMI may underestimate due to **Larger Footprint with No Ice Scattering Signal**

TMI may overestimate due to **Strong Ice Scattering Signal in Anvil Cloud**

Peak Time of PR/TMI and TB

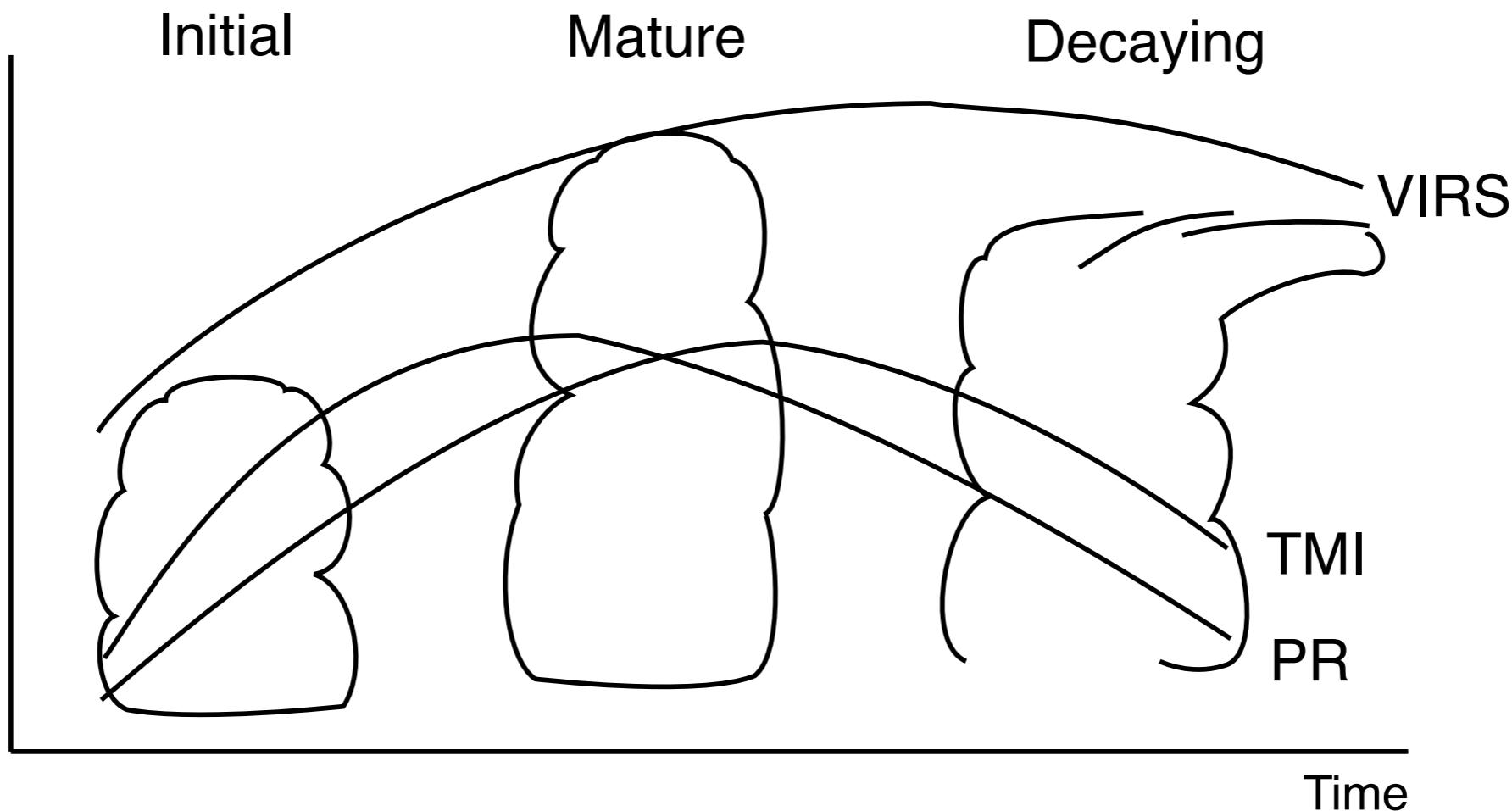


Figure 10: Relationships between sensor signatures and the development of a convective precipitation system. Clouds show development stages. The lines show peak time frequencies in rain rate for each stage for PR and TMI and in brightness temperature for VIRS.

(Yamamoto et. al 2006)

Peak Time of PR/TMI and TB

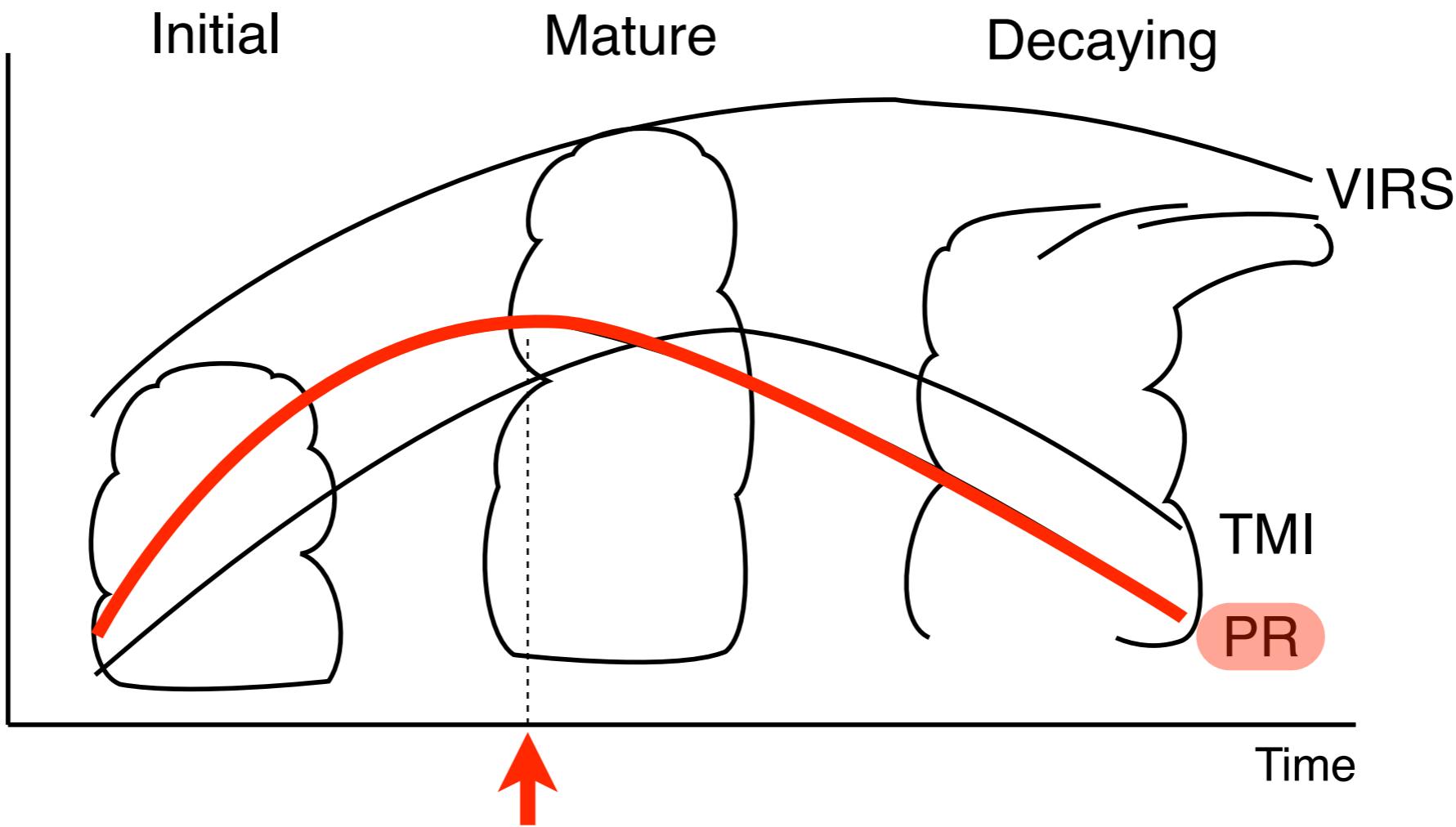


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Peak Time of PR/TMI and TB

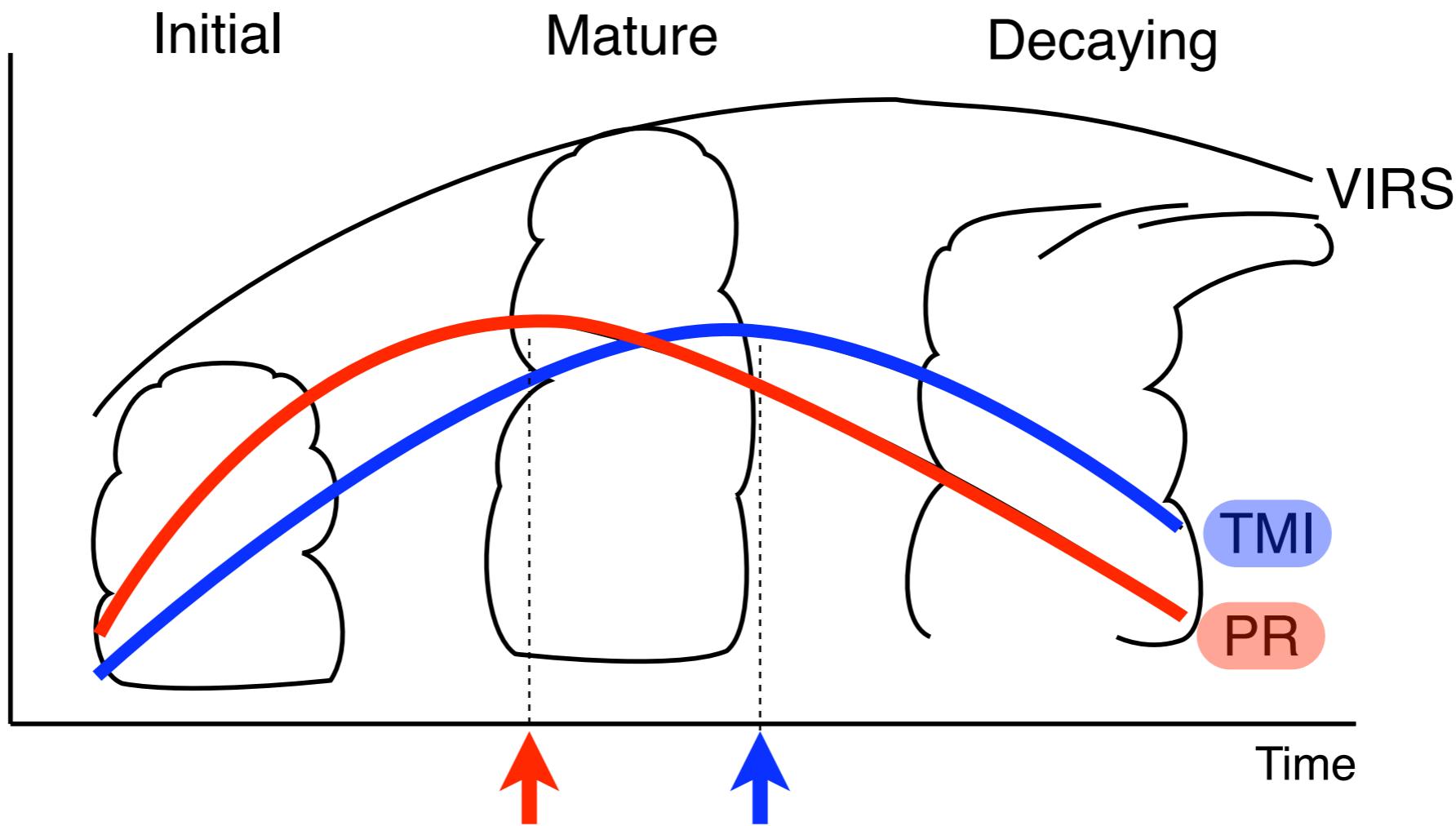


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(Yamamoto et. al 2006)

Peak Time of PR/TMI and TB

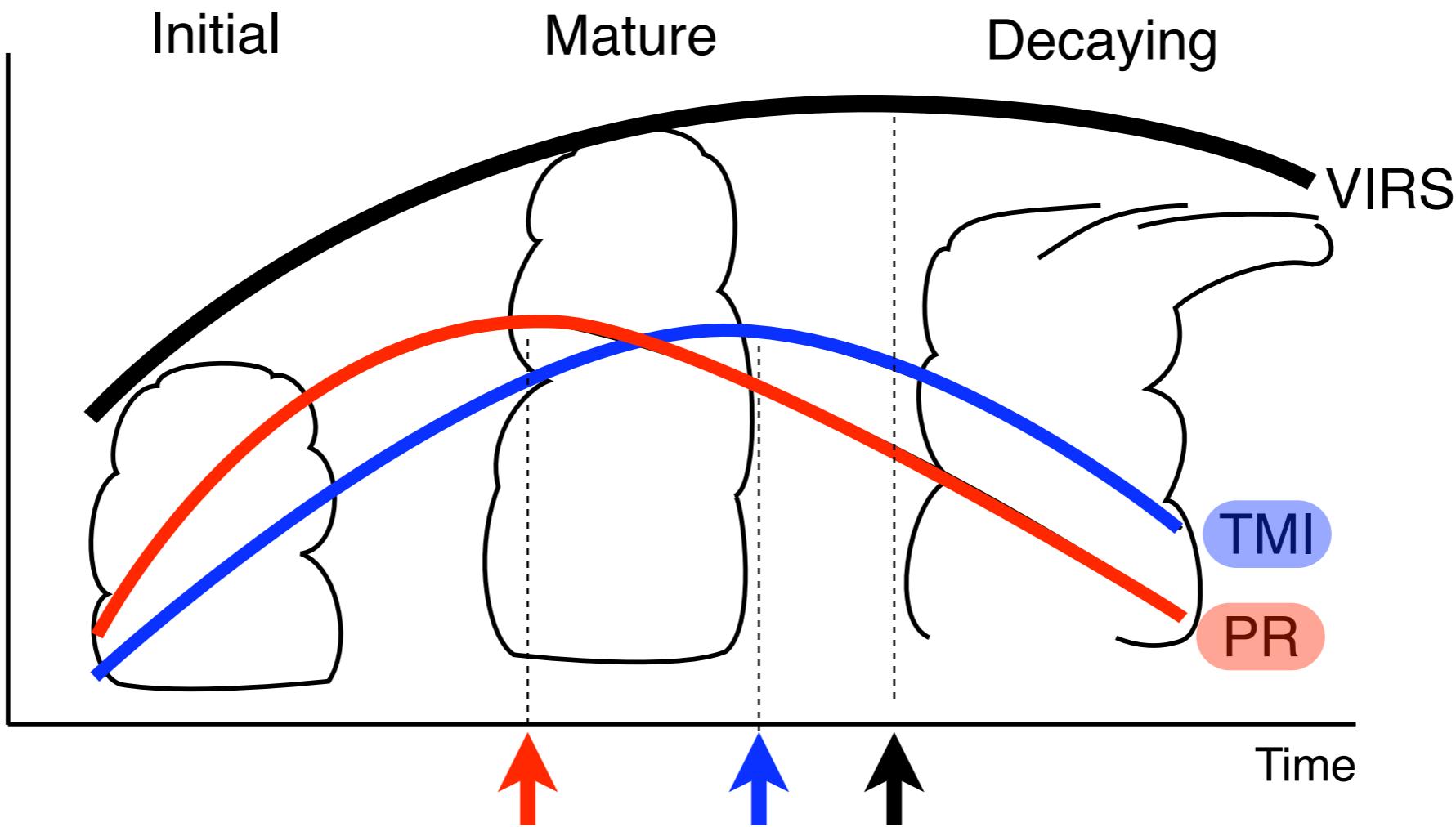
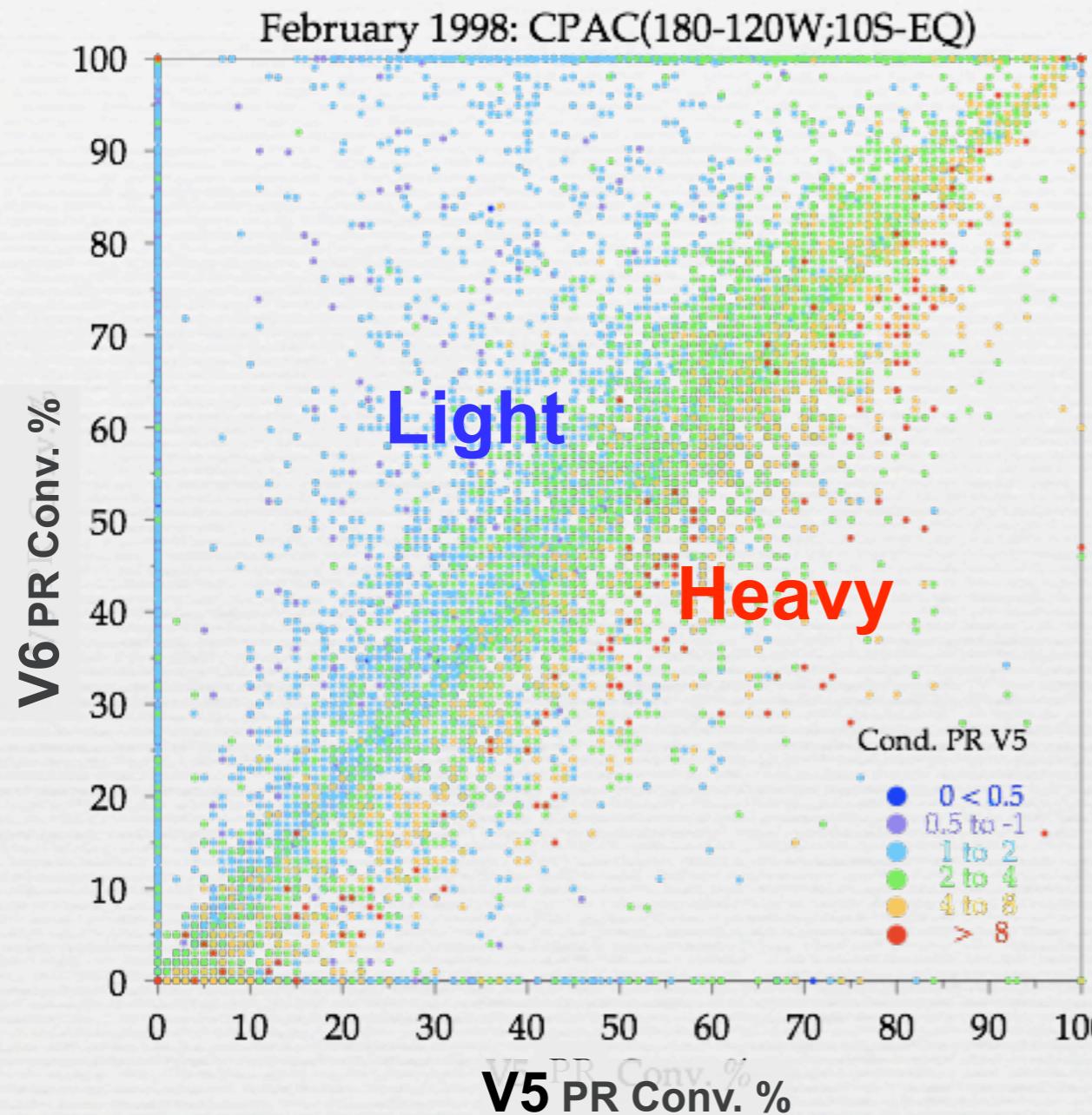


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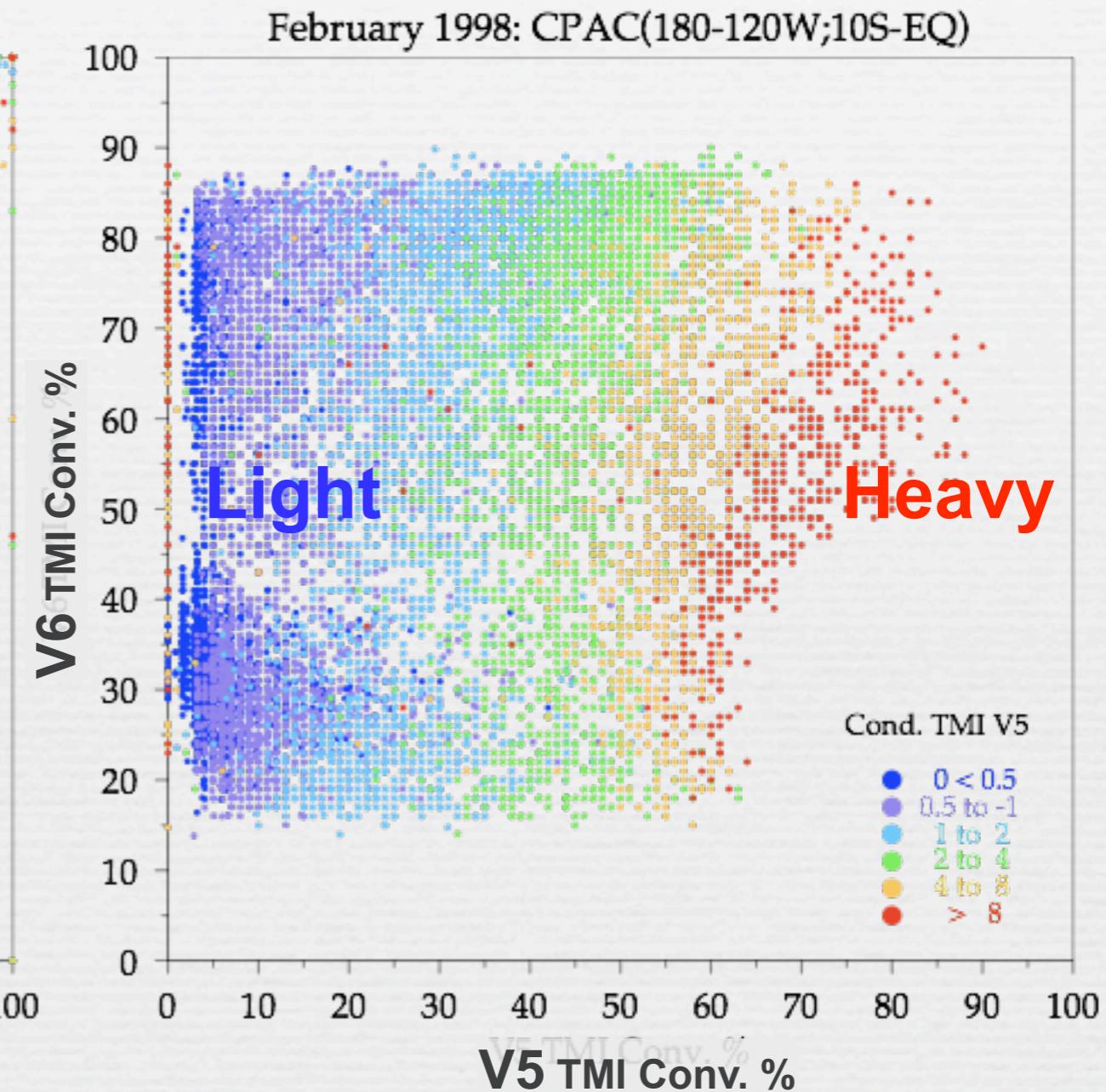
(Yamamoto et. al 2006)

Conv. % Change from V5 to V6

Cond. PR



Cond. TMI



Most Points along the 45 ° Line - Small Changes in V6

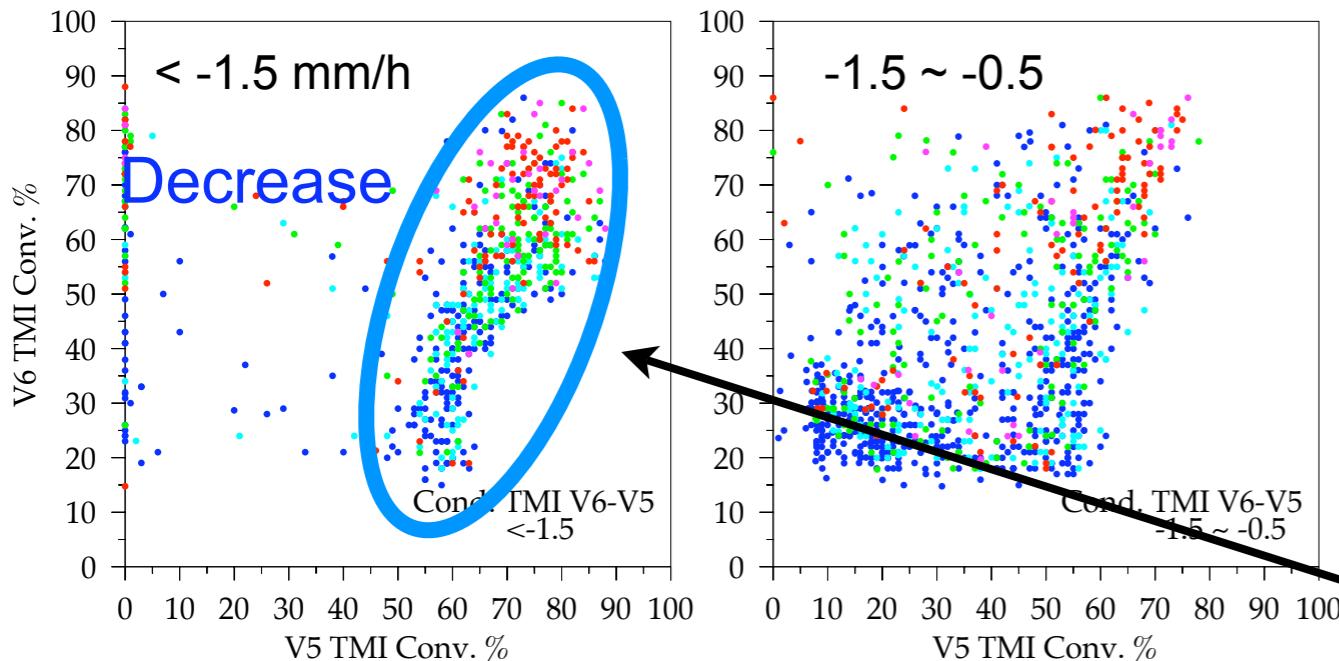
Conv. % Decrease in V6 for Heavy Rain
Conv. % Increase for Light Rain

Large Scattering over the Domain - Large Changes in V6

Cond. V5 TMI Rainrate is proportional to V6 TMI Conv. %

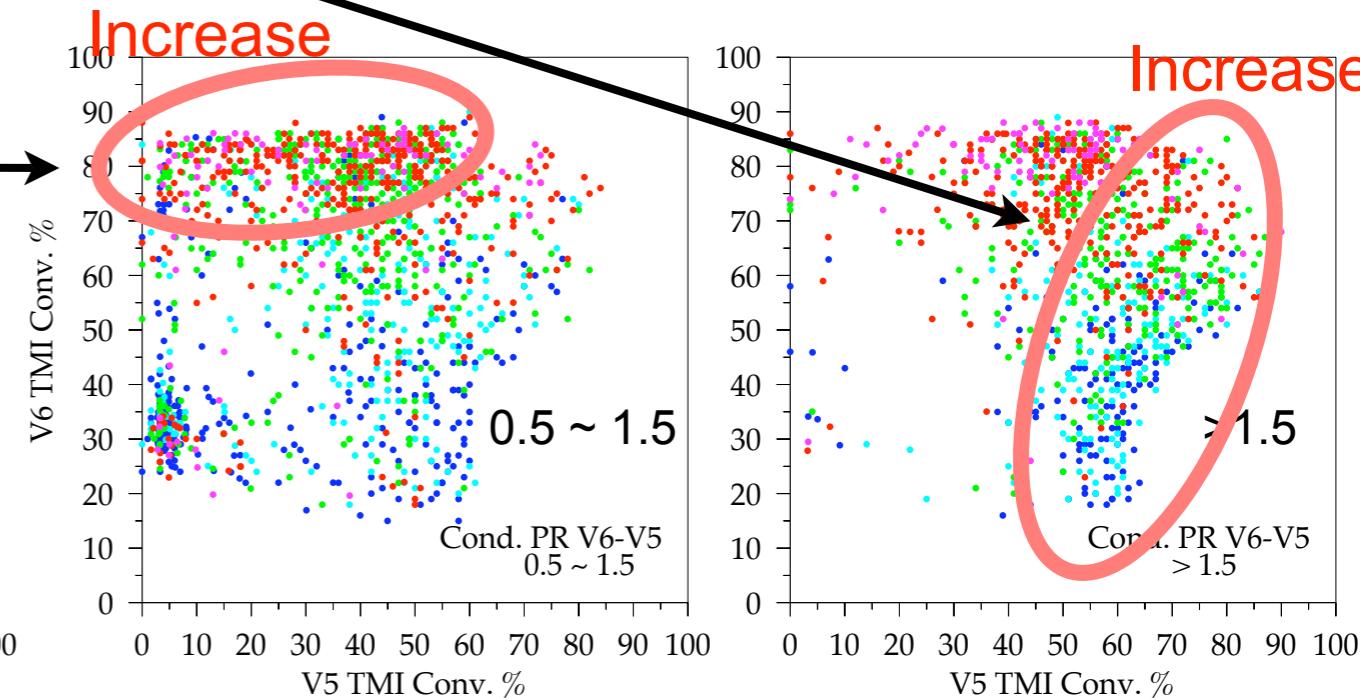
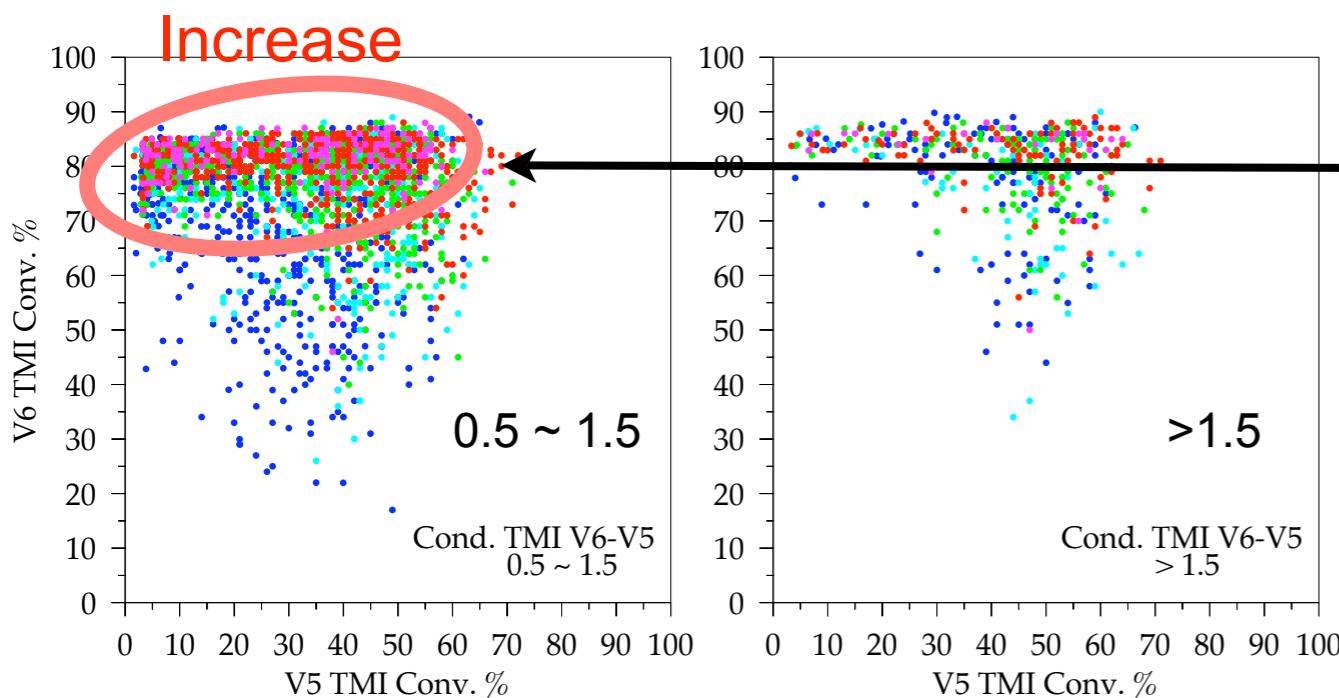
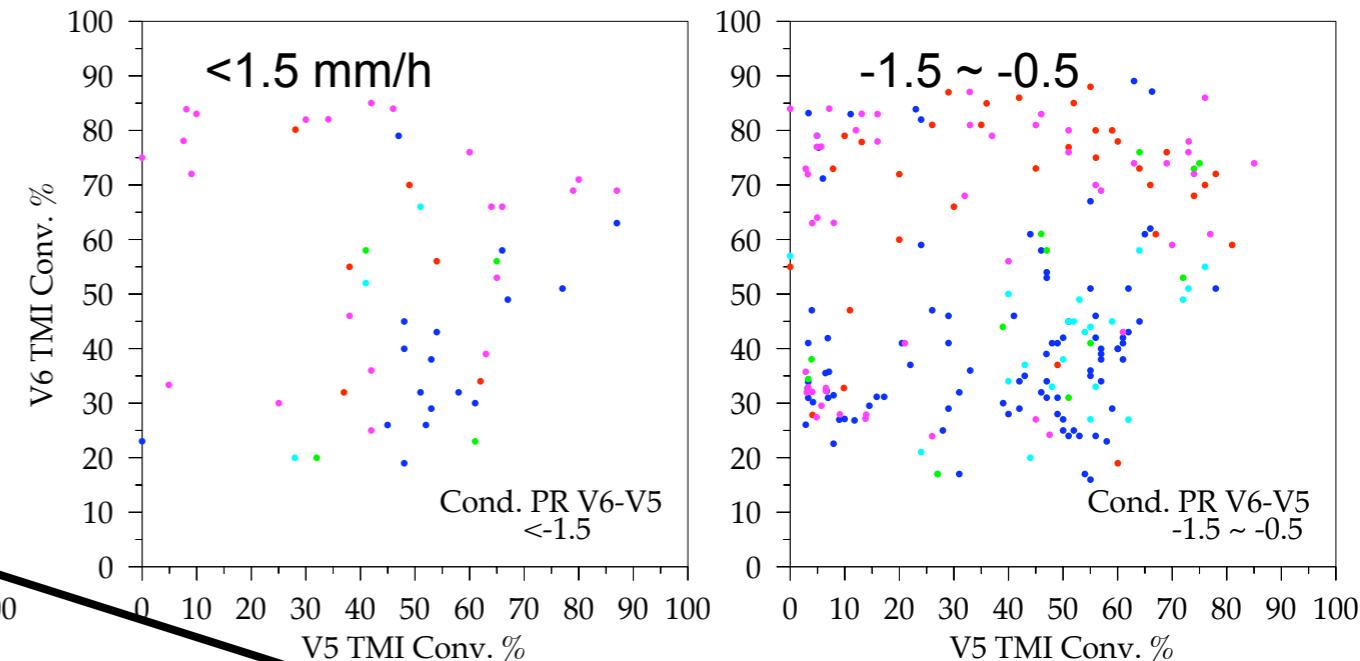
Cond. TMI V6-V5

February 1998: CPAC(180-120W;10S-EQ)



Cond. PR V6-V5

February 1998: CPAC(180-120W;10S-EQ)



V5 PR Conv %

- <20
- 20~40
- 40~60
- 60~80
- 80~100

V5 PR Conv %

- <20
- 20~40
- 40~60
- 60~80
- 80~100

Summary

- **MJO Family**
 - Largest Organized Convection over the Globe
 - Interaction between Convection and Tropical Waves
- **Typhoon / Hurricane**
 - Precipitation Structure
- **Precipitation Systems**
 - Characteristics of Size
 - Life Stages of Systems
 - Long-term Change in terms of Boost effect